This investigation was conducted under the 「Act on the investigation and inquiry into the marine accident」 and its aim is to improve safety of life at sea and prevent the recurrence of similar accidents in the future.

Investigation system in the Republic of Korea is composed of three-tier rulings. This interim report is based on our second ruling.

This report focused on analyzing and identifying the causes and contributory factors. It should not be used for purposes other than safety investigation.

Marine pollution accident from the collision between crane barge Samsung No. 1 towed by tugboats Samsung T-5 and Samho T-3, and oil tanker Hebei Spirit

Prepared by

The Korean Maritime Safety Tribunal

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[Diagram]

[Table]

1. Summary

The towing fleet composed of tugboat Samsung T-5, tugboat Samho T-3, anchor boat Samsung A-1, and crane barge Samsung No. 1, left the Incheon Bridge construction site at around 14:50 on 6 December 2007, and began to sail toward Geoje City in southern area of Republic of Korea. At around 23:30, the towing fleet began to gradually lose its towing ability due to the heavy weather on outer seas of the Yellow Sea. At around 04:00 on 7 December 2007, the weather got worse that the towing fleet attempted to take shelter returning to Incheon Port, but Samsung No. 1 continued to drift East due to heavy seas, that the fleet gave up taking shelter at around 05:17 and resumed the intended towing voyage.

Under the heavy weather, the towing fleet couldn't keep the intended course, continued to drift South with 1.5 knots, and approached Hebei Spirit anchored. At 06:54, Samsung T-5's towing wire snapped due to excessive tension. Even if Samsung No.1 dropped emergency anchor, it collided with Hebei Spirit at approximately 253° and 5 miles from the Sindotaseo lighthouse in Wonbuk-myeon, Taean-gun in South Chungcheong Province, Republic of Korea, (at Latitude 36°52'16"N and Longitude 126°03'02"E), at around 07:06 on 7 December 2007.

Hebei Spirit loaded with about 263,944.5 tons of crude oil, arrived at Daesan Port, anchored with 9 shackles of chain on deck on 6 December 2007 at about 19:18, and was waiting for single buoy mooring the following day.

On the next day early morning when the towing fleet with 1.5 knots slowly approached Hebei Spirit, the Chief officer could not realize the risk of collision at the early stage. Master of Hebei Spirit used the main engine dead slow astern with slackening anchor chain but failed to avoid collision.

As a result of the collision, Hebei Spirit got 3 holes on the port side tanks nos. 1,3, and 5, and leaked 12,547 kl of crude oil.

2. Facts

2.1 Ships' details

Ship name	Samsung T-5	Samho T-3	Samsung No. 1	Hebei Spirit
Port registry	Geoje City	Busan	Geoje City	Hong Kong
Ship owner	Samsung C&T Corporation	Samho I&D Co., Ltd.	Samsung C&T Corporation	Hebei Spirit Shipping Co., Limited
Ship operator	Samsung Heavy Industries Co., Ltd.	Samsung Engineering & Construction Co., Ltd.	Samsung Heavy Industries Co.,Ltd	
Ship manager	Boram Co., Ltd.	Samsung Engineering & Construction Co., Ltd	Boram Co., Ltd.	
Gross tonnage	292 tons	213 tons	11,828 tons	146,848 tons
Engine type & output	Diesel engine 2 sets of 1,765 kw	Diesel engine 2 sets of 1,323 kw	Non power barge	Diesel engine 1 set of 20,594 kw

2.2. Date and time of accident: At around 07:06 on Dec. 7, 2007

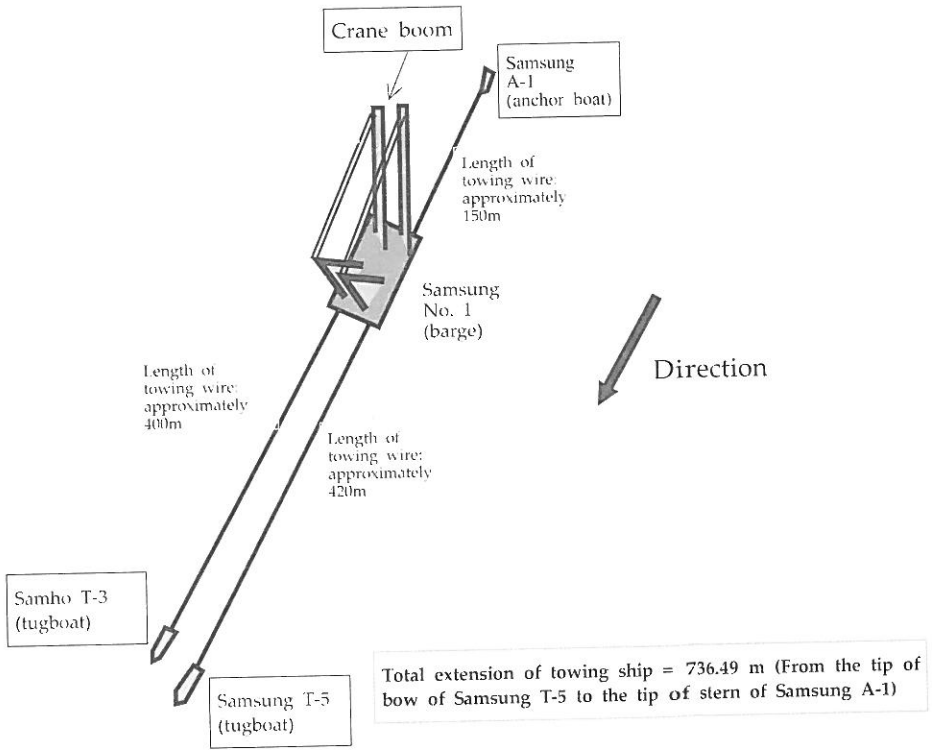
2.3. Place of accident: Latitude 36°52'16"**N** and Longitude 126°03'02"E (253° approximately 5 miles off the Sindotaseo lighthouse in Wonbuk-myeon, Taean-gun, South Chungcheong Province, Republic of Korea)

2.4. Details of the towing fleet

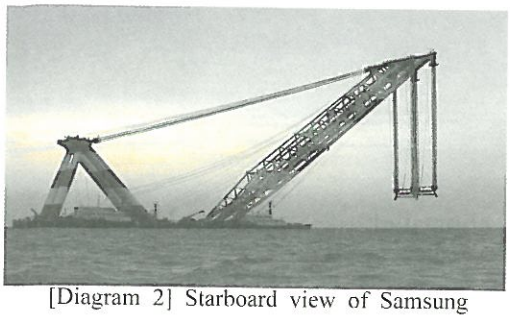
2.4.1. Arrangement of the towing fleet

The towing fleet involved in the accident consisted of Samsung No. 1, a large-sized crane barge; two tugboats, Samsung T-5 and Samho T-3, which pulled Samsung No. 1 in reverse direction by linking a towing wire each on the end of the barge's stern. Anchor boat Samsung A-1 of Samsung No. 1 additionally controlled the course of Samsung No. 1, by following it with a towing wire connected to the barge's bow. (Diagram 1 to Diagram 5, Table 1)

Main duties of Samsung A-1 were to drop and recover the positioning anchor of barge Samsung No.1, while in port. Samsung No. 1 is an 11,828 G/T large-sized crane barge installed with a safety working load of 3,000 tons. It is not under the application of the ISM Code.



[Diagram 1] Arrangement of the towing fleet



[Diagram 2] Starboard view of Samsung No. 1

[Diagram 3] Stern view of Samsung No. 1

[Diagram 4] Samsung T-5

[Diagram 5] Samho T-3

[Table 1] Details related to the ships belonging to the towing fleet involved in the accident

Ship name	G/T Length x width x depth (unit: meter)	Use Registered port	Main engine (propeller type)	Owner Operator
Samsung No. 1 (crane barge)	11,828	Crane barge	Non-power (towed barge)	Samsung C&T Corporation
	105.63 x 45.0 x 7.0	Geoje City		Samsung Heavy Industries Co.,Ltd
Samsung T-5 (lead tug)	292	Tug boat	1,765kw x 2 units(approximately 4,800 HP) (C.P.P)	Samsung C&T Corporation
	35.69 x 10.0 x 4.6	Geoje City		Samsung Heavy Industries Co.,Ltd
Samho T-3 (assist tug)	213	Tug boat	1,323kw x 2 units(approximately 3,600 HP)(Z-peller)	Samho I&D Co., Ltd.
	30.81 x 9.4 x 4.15	Busan		Samsung Heavy Industries Co..Ltd
Samsung A-1 (Anchor boat)	89	Work ship	317kw x 2 units(approximately 805 HP)(F.P.P)	Samsung C&T Corporation
	25.17 x 7.8 x 2.85	Geoje City		Samsung Heavy Industries Co.,Ltd

2.4.2. Shipowner and operator of the towing fleet

Ownership, operation, and safety management relationship of the towing fleet are detailed in four contracts.

2.4.2.1 Contract for consigned management of construction machine: Long-term Leasehold Contract between Samsung Construction Co., Ltd. (hereinafter referred to as "Samsung Construction") and Samsung Heavy Industries Co., Ltd. (hereinafter referred to as "Samsung Heavy Industries")

From the four ships that consisted of the towing fleet, Samsung No. 1, Samsung T-5, and Samsung A-1, excluding Samho T-3, were subject to the "Consignment management contract for construction machine" signed on 29 December 1995, with Samsung Heavy Industries, which had leased them from the owner, Samsung Construction, for 12 years, from 1 January 1996 to 31 December 2007, on the condition of paying annual lease of a certain amount. According to Article 8 (Responsibilities of Accident) of the contract, the lessee, Samsung Heavy Industries, was to be responsible for all these ships' accidents arising from its intentional or gross negligent act(s). According to the contract's name, the contract is a consignment management contract that sets forth Samsung Heavy Industries as paying lease to the owner, Samsung Construction, that this could be viewed as constituting a chartered contract.

2.4.2.2 Service contract of equipment management consignment: consignment management contract between Samsung Heavy Industries and Boram Co., Ltd., (hereinafter referred to as "Boram Co., Ltd.")

Samsung Heavy Industries, which chartered the three above ships from Samsung Construction, entered into the "service contract of equipment management consignment" for one year, from March 1, 2007 to February 29, 2008, with Boram Co., Ltd. for consigning the management of the ships.

Accordingly, Boram Co., Ltd. was to undertake the work involving the operation of towing fleet, work plan, lease of additional tugboats, equipment management and maintenance for safety inspection, and work related to safety management, including that related to the towing operation required in undertaking the work of Samsung Heavy Industries. In addition, with respect to safety management, Boram Co., Ltd. was to be responsible for safety management and comply with the safety management regulations of Samsung Heavy Industries. Samsung Heavy Industries could also dispatch a supervisor to the work site to check the chartered work of Boram Co., Ltd.

It could request work instruction related to the management consignment service from the manager of Boram Co., Ltd., and Boram Co., Ltd. was required to agree unless otherwise having any justifiable cause.

Boram Co., Ltd., which entered into the service contract of equipment management consignment as above with Samsung Heavy Industries, consisted of a total of four officers and employees. It included Representative Director, who had been serving as a director of Samsung Heavy Industries; one employee in charge of work management; one on-site manager, who was a licensed marine Chief Engineer; and one female employee.

A safety management system or a safety management manual on the operation of the towing fleet was not prepared, and human resources and/or specialization with respect to safety management of the towing operation was lacking, to the extent that the safety management of the towing operation was left to the Master of the tugboat and the head of the fleet exclusively.

2.4.2.3 Lease contract of the towing fleet for marine cranes: service contract between Samsung Heavy Industries and Samsung Construction

Samsung Heavy Industries, which leased in the long-term three tugboats from Samsung Construction, entered with Boram Co., Ltd. into the "service contract of equipment management consignment" as above.

It further entered into the "lease contract of the marine crane fleet" with Samsung Corporation Co., Ltd. for 14 days, from 26 November 2007 to 9 December 2007. This contract mixed Samsung Construction and Samsung Corporation Co., Ltd. as the lessee, but according to the certificate of the ships' nationality, the owner of these three ships is Samsung Corporation. Therefore, Samsung Construction and Samsung Corporation were the same body under the said contracts, in which Samsung Heavy Industries had these three ships released conversely to Samsung Construction (Samsung Corporation).

2.4.2.4 Lease contract of Samho T-3: Samsung Construction leased from Samho I&D Co., Ltd.

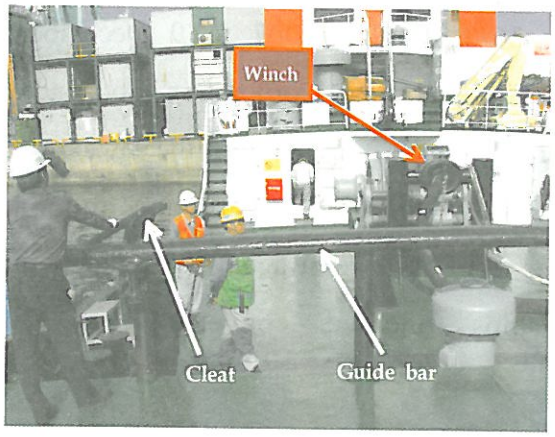
In order to deploy Samsung No. 1 along with Samsung T-5, in the towing voyage from Samsung Heavy Industries in Geoje City to the Incheon Bridge's construction site located in Incheon Port, Samsung Construction, had leased Samho T-3 from Samho I&D Co., Ltd. on Nov. 19, 2007 from Nov. 26 to Dec. 12, 2007.

2.4.3. Towing equipment

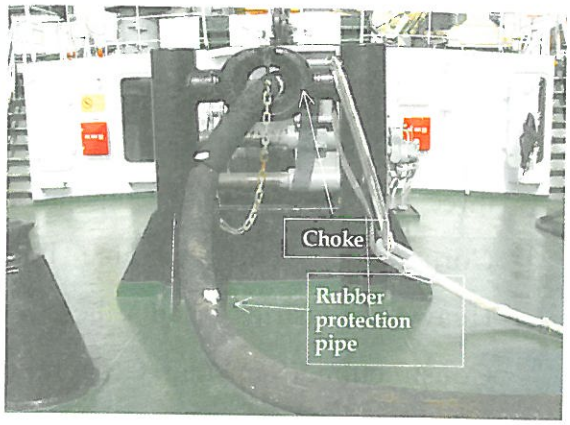
2.4.3.1. Towing equipment of Samsung T-5 and Samho T-3

One unit of towing winch (hereinafter referred to as the "towing winch") was installed on the central part of the poop deck of Samsung T-5 and Samho T-3, to wind and unwind the main towing wire and the transverse horizontal rail (hereinafter referred to as the "Guide Bar") on the central part of the stern deck was erected so that the towing wire would cross the deck longitudinally without touching it.

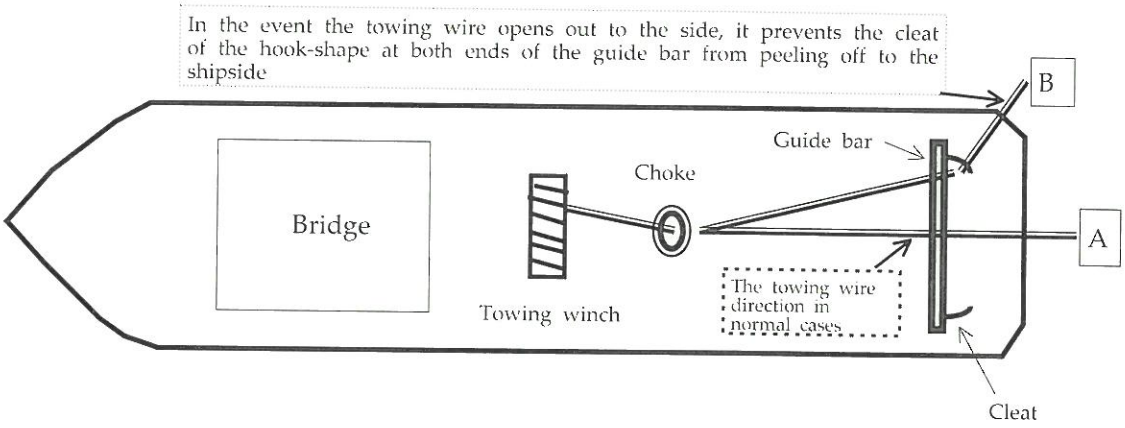
At the end of both sides of the guide bar, the towing wire had a hump in the shape of a hook (hereinafter referred to as the "cleat"), to prevent the towing wire from getting out of the longitudinal centerline of the ship body and skidding out to the ship's side (Diagram 6, Diagram 8).



[Diagram 6] Towing winch, guide bar and cleat on poop deck of Samsung T-5



[Diagram 7] Towing wire choke and rubber protection pipe behind the towing winch of Samsung T-5



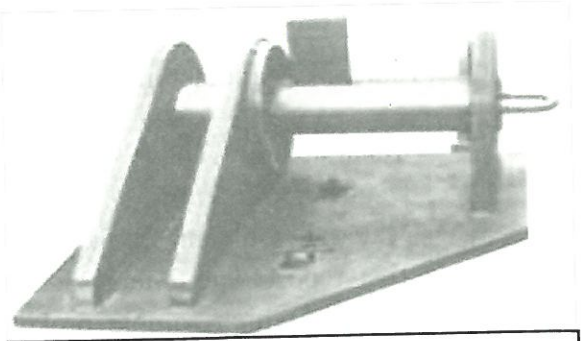
[Diagram 8] Course (A), in which the towing wire - which enters and unwinds from the towing winch - passes through the choke and guide bar; this is the normal case where the wire leaves straight toward the stern. Course (B) portrays the image of preventing the wire from coming off the hook at the cleat at the tip of the guide bar when it opens out.

The towing wire passes the round choke straight behind the towing winch. It winds and unwinds from the towing winch, and if the angle of the towing wire opens out widely to pass the choke, it passes the thick rubber protection pipe to protect it from

the damage ([Diagram 7]), and the seaside's end of the towing wire is made of a round eye to use the intermediary towing wire as a stretcher or a pennant wire that connects to the towed ship.

In the case of this accident, it was connected to the smit bracket attached to both ends of the poop deck of Samsung No. 1 ([Diagram 7] [Diagram 9] and [Diagram 10]).

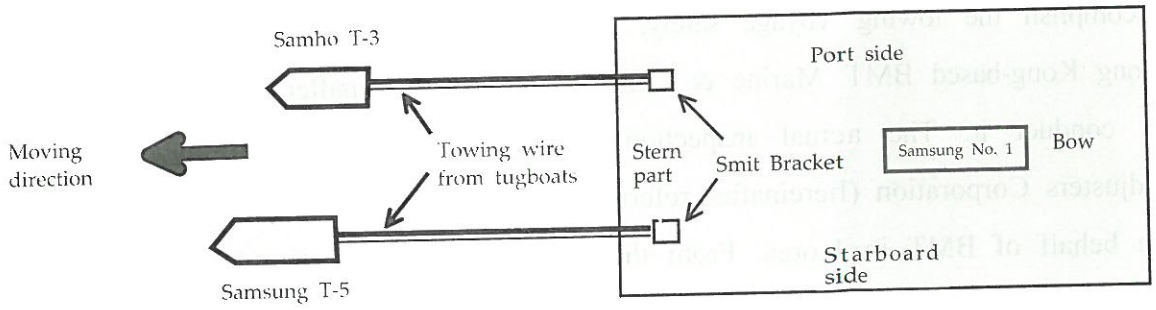
[Diagram 9] Eye at the end of the towing wire wrapped around the towing winch



[Diagram 10] Smit bracket attached on starboard and portside of the poop deck of Samsung No. 1

2.4.3.2. Towing equipment of Samsung No. 1

On Samsung No. 1, a smit bracket that connects the towing wires, was attached to the port side and starboard side each on the poop deck to secure the intermediary towing wire or pennant wire of the stretcher. But during this accident, towing wires were connected each to the Samsung T-5 starboard side (the tugboat towed the stern of Samsung No. 1, that it would be the port side if based on the moving direction) and Samho T-3 port side. ([Diagram 11])



[Diagram 11] The towing wire of Samsung T-5 and Samho T-3 were connected to the smit bracket attached to the deck floor of Samsung No. 1's stern.

2.4.3.3. Manufacturer's test report on Samsung T-5 towing wire

At the time of the accident, the broken towing wire of Samsung T-5 was a Japanese product purchased in 1995 and used as a luffing wire for the Samsung No. 1 crane. It was kept in the ship after use. But the wire began to be used again as a towing wire on June 26, 2007, approximately five months before the accident, and had a breaking load and safe work load of 217 tons and 99 tons, respectively. ([Table 2])

[Table 2] Manufacturer's test report of Samsung T-5 towing wire

Manufacturer: Tokyo Rope MFG. Co. Ltd Diameter: 47.5mm Material: Galvanized flexible steel wire rope Test report date: Mar. 23, 1995 Load at which sample broke: 217 tons Safe work load: 99 tons

2.4.4. Towing operation test (hereinafter referred to as "towing test")

Samsung Heavy Industries Co., Ltd. had an insurance survey conducted at its own cost at Busan Port on November 26, 2007, in order to subscribe to a ship insurance of Samsung Fire & Maritime Insurance Co., Ltd. (hereinafter referred to as "Samsung Fire") in preparation for marine risks expected during the towing operation from Geoje City to the Incheon Bridge construction work site in Incheon Port.

This inspection was to confirm to the insurer that the towing fleet is appropriate to accomplish the towing voyage safely. Samsung Heavy Industries Co., Ltd. had asked Hong Kong-based BMT Marine & Offshore Survey (hereinafter referred to as "BMT") to conduct it. The actual inspection was undertaken by Hyopsung Surveyors & Adjusters Corporation (hereinafter referred to as "Hyopsung Surveyors"), which worked on behalf of BMT in Korea. From the test report, only parts related to the accident have been excerpted.

2.4.4.1. Voyage recommendation

Hyupsung Surveyors had specified voyage recommendations to Samsung Heavy Industries Co., Ltd. to comply with for the safe towing voyage, when it issued the Samsung No. 1 Insurance Survey Certificate upon completion of the towing test. Voyage recommendations are as in [Table 3].

[Table 3] Voyage recommendations to the towing fleet to comply with, as specified in the Samsung No. 1 towing insurance certificate

1. Towing voyage should start within 7 days upon issuance of the insurance certificate.
2. **Must leave and enter port during the day.**
3. **If wind force exceeds Beaufort Scale 5, do not depart.**
4. **The length of the towing wire has to be adjusted by the Master according to the weather condition but should not touch the sea bottom.**
5. The maximum towing speed shall follow the decision of master but the safe speed should be maintained.
6. When visibility is limited, the length of the towing wire should be shortened.
7. There should be enough fuel to last 3 days beyond reaching the destination port or an intermediary oil supply port.
8. Select as much as possible a straight route of the shortest distance.
9. Maintain communication at certain interval between the tugboat and the towed ship.
10. Listen to weather forecasts before departing and listen often to weather forecasts provided by weather authorities during the voyage.
11. **When there is a problem on the towing fleet, such as a breakdown of towing equipment, an engine trouble on tugboat or towed ship, slanting of towed material due to water ingressing, or any deviation, immediately inform the ship owner and the insurance surveyor in order to receive the required measures.**

Conclusion: Samsung T-5 and Samho T-3 are appropriate for towing voyage of Samsung No. 1 from Geoje City to Incheon. Samsung No. 1 is in fine condition without any risk normally not acceptable to the insurer. (However, the condition is to duly comply with this voyage recommendation.)

2.4.4.2. Towing equipment according to the Salvage Association's Towage Approval Check List for Floating Crane Barge

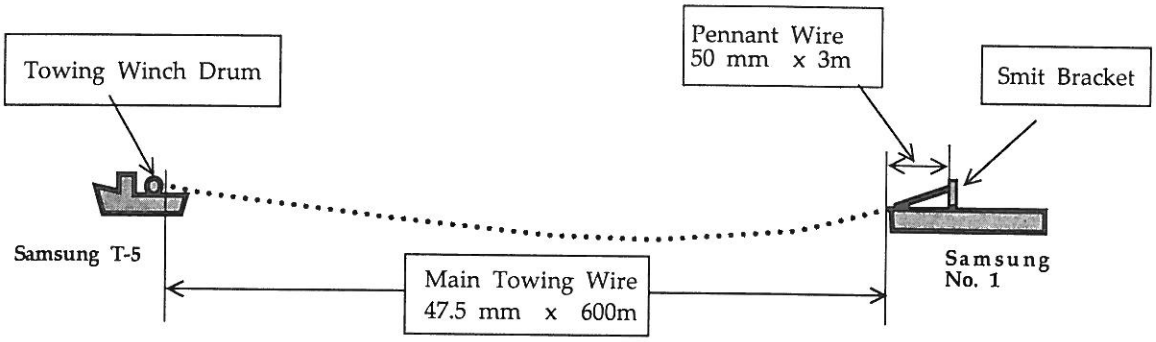
On the Salvage Association's Towage Approval Check List for Floating Crane Barge (hereinafter referred to as the "towing approval check list"), a part of the inspection report, there was a detailed, separate list on the arrangement of tugboats while towing, and on the towage connection and equipment to be used during towing voyage, such as the composition, length, material of the towing wires of Samsung T-5 and Samho T-3 as a condition to approve the towing test result as appropriate. However, the length of the towing wire was permitted to be adjusted by the tugboat's Master pursuant to Paragraph 4 of the above voyage recommendation. According to the content, the towing wire structure of these two tugboats is shown as follows.

2.4.4.2.1. Towing equipment of Samsung T-5: lead tug ([Diagram 12])

Main towing wire: Steel wire rope of 47.5mm in diameter and 600m in length from the tugboat's towing winch (hereinafter referred to as the "steel wire rope")

Pennant wire: Steel wire rope of 50mm in diameter and 3m in length connected to the smit bracket installed on the starboard side stern of Samsung No. 1 (the port side based on the moving direction)

※ The main towing wire and the pennant wire are connected with a shackle.



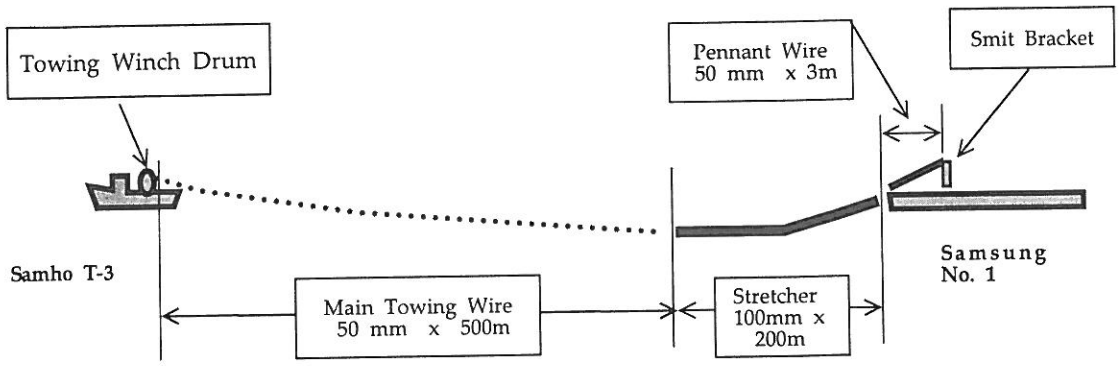
[Diagram 12] Structure of Samsung T-5 towing wire on the towing approval check list (the total length of the towing wire is 603m, but the pennant wire is placed on the deck of the barge, that the available maximum length of the towing wire is 600m, and the actual length during navigation is appropriately adjusted by the Master.)

2.4.4.2.2. Towing equipment of Samho T-3 ([Diagram 13])

Main towing wire: Steel wire rope of a diameter of 50mm and length of 500m from the tugboat's towing winch

Pennant wire: Steel wire rope of 50mm in diameter and 3m in length is connected to the smit bracket installed on the port side stern of Samsung No. 1 (starboard side based on the moving direction)

Stretcher: Between the main towing wire and the pennant wire, the synthetic fiber rope (hereinafter referred to as the "PP Rope") of 100mm in diameter and 200m in length, is additionally connected.



[Diagram 13] The structure of Samho T-3 towing wire on the towing approval check list (unlike the towing wire structure of Samsung T-5, the stretcher of the PP rope was added to absorb the tension impact between the main towing wire and the pennant wire. The pennant wire is placed on the deck of Samsung No. 1, that Samho T-3 towing wire's available maximum length is 700m, and the actual length during navigation is adjusted appropriately by the Master.)

2.4.4.3. Bollard pull of tugboats

Under the towing approval check list, the main engine output and bollard pull of Samsung T-5 and Samho T-3 are 55 tons at 4,800 HP and 46.4 tons at 3,600 HP, respectively. On 9 December 1995, about 12 years before the accident, Daesun Shipbuilding conducted a bollard pull test on Samsung T-5 and the result showed a maximum value of 57.84 tons ([Table 4]).

[Table 4] Summary of bollard pull test result of Samsung T-5 conducted by Daeseon Shipbuilding on 9 December 1995

No. of tests	RPM of main engine	RPM of propeller	Main engine BHP (PSI)	bollard pull (ton)	Revised coefficient	Revised bollard pull (ton)
1st	797	213	1215	33.94	1.0485	35.59
2nd	909	243	1745	44.79		46.96
3rd	965	257	2035	50.47		52.92
4th	997	265	2210	55.16		57.84

2.4.5. Anchor of Samsung No. 1

The anchor of Samsung No. 1 was dropped in emergency before the collision between barge Samsung No. 1 and oil tanker Hebei Spirit. In order to review the appropriateness of related items, anchor specifications, and the anchor chains are considered hereto.

2.4.5.1 Anchor

- Type: HHP (High Holding Power Type)
- Weight: 19,700 Kg.
- Diameter of anchor chain: 97 mm.
- Length of 1 shackle: 27.5m. Weight per 1m in length of anchor chain: 206kg.
- Total length of anchor chain: 15 shackles (412.5m = 27.5 m/shackle x 15 shackles)
- Total weight of anchor chain: 84,975 kg (= 206 kg/m x 412.5)

2.4.5.2 Positioning Anchor ([Diagram 14])

Samsung No. 1 has an anchor for anchoring and four positioning anchors, dropped to fix the ships on a site during crane work. Under normal conditions, anchor boat Samsung A-1 usually carries over the four positioning anchors and drops them at a designated drop point. But under heavy seas, Samsung A-1, a small-sized ship (of approximately 89 G/T, approximately 25 meters in length and approximately 2.8 meters in depth) is not designed to carry out the above-mentioned operation.

[Diagram 14] Positioning anchor and steel anchor buoy in yellow to indicate the location of Samsung No. 1's anchor

2.4.6. Towing fleet operators and their designated duties

During the crane work, the Fleet Manager of the towing fleet, who was also the head of crane barge Samsung No.1, is in charge of the overall operation. However, during towing voyage, Master of Samsung T-5, who is marked as "lead tug" in the towing approval check list, is the official person in command. Along with him, the fleet manager is also actively engaged in commanding the fleet during the voyage in the absence of an established towing voyage command authority.

Master of Samho T-3 (hereinafter referred to as "Master of Samho T-3") assisted the towing voyage of Samsung T-5, in accordance with the hand signal or instruction communicated through very high frequency (hereinafter referred to as "VHF") by Master of Samsung T-5. Therefore, the person under navigational watch at the auxiliary tugboat, Samho T-3, moved in accordance with instructions from the main tugboat, Samsung T-5, such that it was rather passive, unlike the person on navigational watch at Samsung T-5.

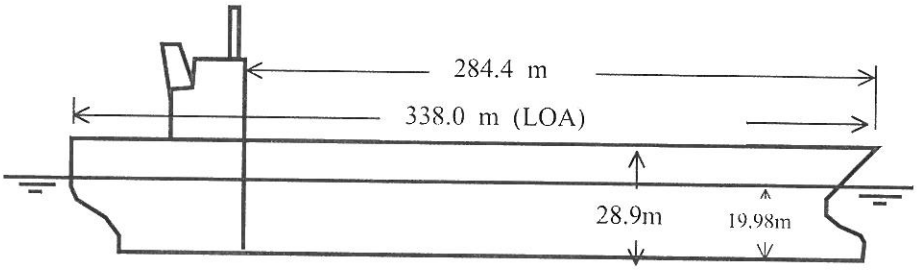
Therefore, the person on navigational watch at Samho T-3 had relatively less interest in the intended ship's course or speed. During the said accident, Fleet Manager of the towing fleet was qualified with several years of experience as a tugboat Master and embarked as the leader of the towing fleet since around April 2003. Master of

Samsung T-5 was qualified with approximately 7 years of experience as a tugboat Master and embarked as the Master of Samsung T-5 since November 18, 2003. Master of Samho T-3 had approximately 20 years of total experience, was qualified to work as the Master, and embarked as the Master of Samho T-3 since April 2003.

2.5. Details of oil tanker Hebei Spirit

2.5.1. Ship dimension

Hebei Spirit's dimension is shown as follows [Diagram 15].



[Diagram 15] Hebei Spirit's dimension

2.5.2. Equipment

2.5.2.1. Navigation equipment

Major navigation equipment used in the process leading up to the accident are shown as follows.

ARPA radar: 2 units	AIS: 1 unit
GPS: 2 units	Auto Chart Plotter: 1 unit

VDR (Voyage Data Recorder) is a SVDR (Simplified VDR), first loaded on July 30, 2006, that had completed an annual survey by CCS (Chinese Classification Society) and LR (Lloyd's Register of Shipping) on June 17, 2007. Information related to the ship's navigation was automatically inputted and saved at a certain time interval. Saved information was information related to navigation of the last 12 hours, and the type of information saved was the minimal information related to navigation. ([Table 5])

[Table 5] Hebei Spirit's VDR saved information

Information	Equipment
Ship location	GPS
Speed	Doppler
Heading	Gyro
Water depth	Echo Sounder
Content of communication	VHF
On-ship calls and communication on bridge	Microphone in the ship

2.5.2.2. Anchoring facilities (anchor)

Type: AC-14 (Stockless) Weight: 15,000Kg Windlass speed: 9 m/min.

Length of 1 shackle: 27.5 m Weight per 1m in length: 270 kg

Total length: 14 shackles (385 m = 27.5 m x 14 shackles)

Total weight: 103,950 kg

2.5.2.3. Main engine and propeller

Manufacturer of main engine: Man B&W

Output: Diesel engine of 20,594 kw, 1 unit (approximately 28,000 HP)

Propeller: Fixed pitch propeller, 1 unit

The RPM and estimated thrust for each service stage of the ship's main engine is shown in [Table 6].

[Table 6] Thrust of Hebei Spirit's main engine

Speed	Propeller RPM	Forward thrust (ton)	Backward thrust (ton)
Navigational Full ahead	68	342	
Full ahead/astern	49	173	134
Half ahead/astern	43	131	101
Slow ahead/astern	36	91	68
Dead slow ahead/astern	25	41	26

The ship's main engine can be remotely controlled from the ship's bridge. When entering and leaving port, the main engine is controlled from the bridge. The ship's main engine has an engine protection system, such that in the event of engine troubles, such as abnormal high temperature of coolant and others, an alarm rings and automatically slows down the engine. During auto slow down, the main engine operates at a speed below dead-slow.

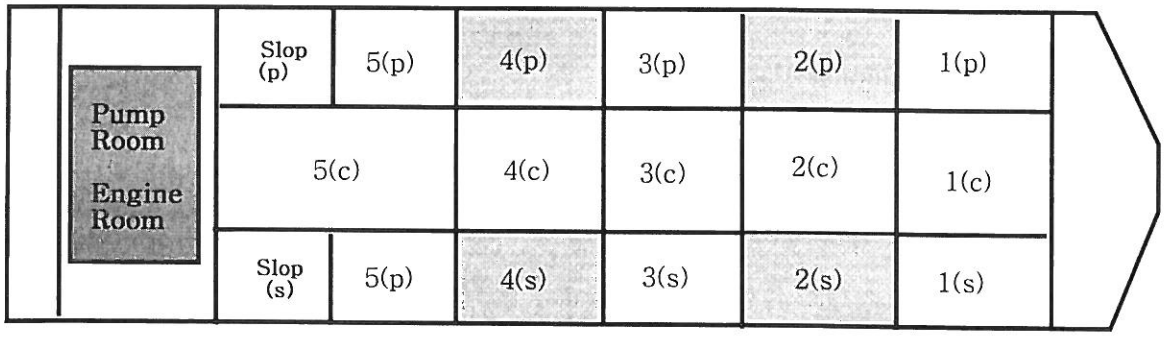
In order to restore the auto slow down to normal condition, the cause must first be removed and the auto slow down condition released. Releasing the auto slow down is made possible by lowering the bridge telegraph to below dead-slow speed. In addition, in the event of an emergency, one can undertake emergency operation by pressing the override button on the bridge control stand to stop the engine protection function temporarily.

2.5.2.4. Cargo control equipment

This ship spilled approximately 12,547 kilo-liters of crude oil stored in cargo tank (hereinafter referred to as the "cargo tank"), damaged from the collision. This proceeding must disclose the cause of mass oil leaking and the cargo management equipment required thereto is as follows.

2.5.2.4.1. Tank arrangement and tank capacity

The ship had 13 cargo oil tanks and 4 ballast water tanks. ([Diagram 16], [Table 7])



[Diagram16] The arrangement of cargo tanks and ballast tanks(marked in gray)

[Table 7] Tank arrangement and capacity

Cargo tank	Capacity		Cargo tank	Capacity	
	m^3	BBLS		m^3	BBLS
No. 1 (Center)	31,652.2	199,086	No. 1 (Port · starboard)	22,266.1	140,049
No. 2 (Center)	26,177.0	164,648	No. 3 (Port · starboard)	29,824.1	187,588
No. 3 (Center)	33,656,2	211,691	No. 5 (Port · starboard)	22,267.1	140,056
No. 4 (Center)	26,177.0	164,648	Slop (Port · starboard)	5,519.5	34,717
No. 5 (Center)	38,067.6	239,438			
Sum of 100% cargo tank			315,483.6 m3 / 1,984,331 BBLS		
Sum of 98% cargo tank			309,173.8 m3 / 1,944,644 BBLS		
Difference between 100% capacity and 98% capacity			6,309.7 m3 / 39,687 BBLS (Capacity sum of upper space when loading 98%)		

2.5.2.4.2. Cargo piping system, ballast piping system, inert gas system and others

This ship is a SBT+PL type with a "protective location of segregated ballast spaces" that completely separate the cargo zone from the ballast pipe as a single-hull oil tanker with a keel laid on November 16, 1992 (delivered on October 7, 1993). This ship was subject to the application of the protective location of segregated ballast spaces as stated in MARPOL 73/78 Annex I (Article 12 to 15 of Regulation 18 and Article 2 of Regulation 20,).

This ship's cargo piping system has three cargo oil pumps, each with a pumping capacity of 4,500 m^3 per hour, installed in its cargo oil pump room. Separately thereto, a pump of a capacity per hour of 2,750 m^3, was installed on the COW (Crude Oil Washing) line to wash crude oil in all cargo oil tanks.

The ballast piping is comprised of a ballast pump of a capacity of 750 m^3 per hour installed independently on both sides of no. 2 and no. 4 in the interior of each tank. The sea chest and overboard valve were separately installed on each tank, such that the ballast piping and the cargo piping system were completely separated and operated to allow each ballast water tank to load and discharge ballast water independently, without passing any part of the cargo space.

The cargo oil tank had an inert gas system installed to maintain oxygen below LEL. The boiler exhaust gas released from the engine room was desulfurized, its dust removed and cooled through a scrubber unit using sea water. The gas was then blown into the cargo oil tank by using two blowers through an inert gas pipe installed on the upper deck. Air pressure of the inert gas sent to the cargo oil tank was designed to operate at a certain rated positive pressure (+2,100 mmAq) and negative pressure (-700 mmAq) under the operation of a P/V (pressure & vacuum) breaker.

In addition, each cargo oil tank had a high velocity pressure & vacuum valve (hereinafter referred to as a "high velocity P/V valve") installed, so that in the event of a specific cargo oil tank, it would be independently set from other cargo oil tanks and the pressure of the applicable cargo oil tank would operate at a preset positive pressure (+2,000 mmAq) and negative pressure (-700 mmAq).

2.5.3. Master and Chief officer

2.5.3.1. Hebei Spirit's Master acquired his license to work as a Master in England in 2002, was promoted to Master in 2006, and became the Master of Hebei Spirit on October 12, 2007. Before becoming the ship's Master, he was working for a medium-sized oil tanker and Hebei Spirit was the first assignment on a VLCC.

2.5.3.2. Hebei Spirit's Chief Officer had a total of seven years experience on board a ship and three years as a Chief Officer. Of these, he worked for three and half months on another oil tanker and embarked on Hebei Spirit at Fujaira on November 17, 2007.

2.5.3.3. Anchorage circumstances

When Hebei Sprit approached Daesan Port the day before the accident, it received inforamtion about the anchorage from the VTS center. Under its own discretion, it selected the anchorage out of the port boundary at Latitude 36°52'29"N and Longitude 126°03'14.5"E or 255° and approximately 4.8 off miles from the Sindotaseo lighthouse in Wonbuk-myeon, Taean-gun, South Chungcheong Province, Republic of Korea.

It was at about 7 miles Northwest of the Traffic Separation Scheme (TSS) of Gadaeam-Heukdo, and where the northern access to and fro TSS, and the access route to and fro Incheon Port, Daesan Port, and Pyeongtaek Port, intersect. In addition, it was in the open sea without shelter, where anchorage was deep with water depth of approximately 64 meters and sandy seabed not highly expected to have holding power, and where the maximum tidal flow exceeds 3 knots.

3. Narrative of Accident

3.1. Towing fleet

3.1.1. Departure from and passage through the designated area in port of Inchedn

(6 December 2007 at around 14:50 - same day at around 24:00)

3.1.1.1. Navigation preparation

Master of Samsung T-5 of the lead tug, who was responsible for navigating the towing fleet, was on board this ship on November 18, 2003, and for towing the crane barge Samsung No. 1 from the Incheon Bridge Construction site to Samsung Heavy Industries Co., Ltd. in Gohyeon Port in Geoje City, he acquired weather information on the intended course from the on-site manager of Boram Co., Ltd. and Fleet Manager at around noon of 6 December 2007. According to the information, there would be a wind wave advisory on the far seas in the Yellow Sea around 03:00 on December 7, with a WNW wind blowing 12~16m per second with wave height of approximately 2~4m.

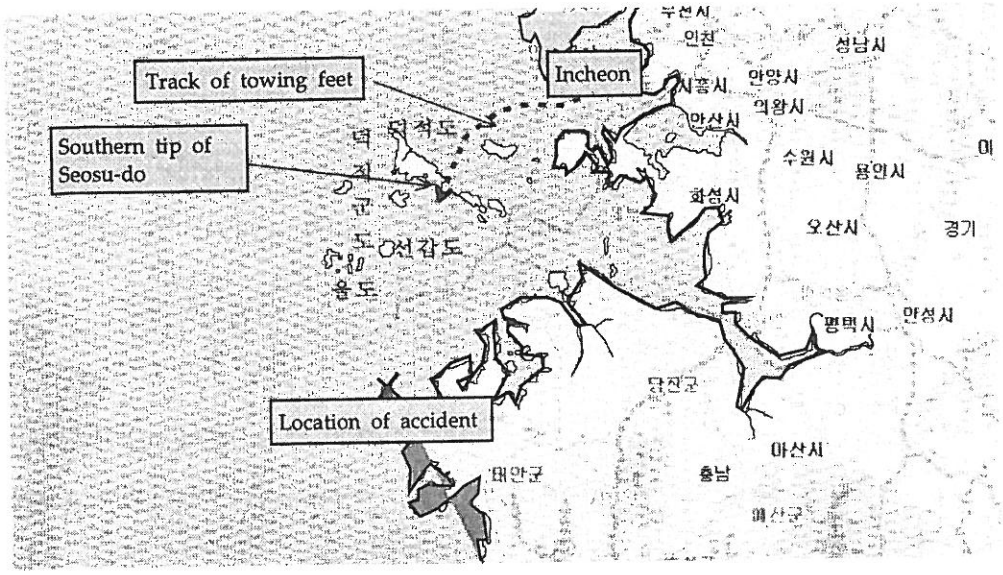
Mater of Samsung T-5 did not check any other weather information, but decided to depart, since the weather at Incheon Port had not reached Beaufort Scale 5, which would have prohibited it from leaving port as specified in the navigation recommendation of the towing insurance certificate. Also, the heavy seas warning for the far seas in the Yellow Sea, was a forecast for seas of 20 miles off the coastal line, while the towing fleet's intended route was to be within approximately 10 miles off the coast, such that the Master deemed the heavy seas would not have an impact on the towing fleet.

Master of Samsung T-5 had Samsung No. 1 towed from the stern by Samsung T-5 and assist tug Samho T-3, side by side, by having steel wire ropes of diameter 47.5mm and 50mm each and length of approximately 200m, respectively, attached to their towing winches. Samsung A-1 connected a steel wire rope of diameter 48mm and length of approximately 150m to the bow of Samsung No. 1 (on the towing fleet's back based on the moving direction), for it to follow the towing fleet. This is how the Master arranged the towing fleet to be when leaving port, since it was sailing within the port right after departure. The draft of Samsung No. 1 had a bow of 4.2m, stern of 2.5m and an average of 3.35m.

Master of Samsung T-5 commanded the towing fleet with such sailing preparations and left the Incheon Bridge construction site at around 14:50 on 6 December 2007. From then on, Samho T-3 received navigation instructions from Samsung T-5 as necessary through VHF channel 15, in order to adjust the ship's course and speed and assist the towing voyage by maintaining a certain distance side by side the starboard side of Samsung T-5.

3.1.1.2 Passing through the designated area of Incheon Port and extending the towing wires

After departing from port, the Master reported to the VTS Center of Incheon Port that the ship had just sailed past Palmido Island at a speed of approximately 4 knots at around 16:00 under manual steering condition. Thereafter, it sailed South along Seosudo Island in the designated area of Incheon Port and passed the island at around 20:30. For coastal navigation, it extended the towing wires of Samsung T-5 and Samho T-3 to approximately 420 meters and 400 meters, respectively. From 16:40, it set the speed at approximately 4.2 knots and the intended course of 206° ([Diagram. 17]). At this time, the tugboats had their mast light, side light, stern light, towing light and others turned on, and Samsung No. 1 had its navigational light along with red, white, and red lights to show the fleet had restricted control ability, and other bright lights for deck work, turned on.



[Diagram 17] Track of towing fleet after departing from Incheon Port to the southern tip of Seosu-do

According to the Salvage Association Towage Approval Check List for the towing fleet, the Master of Samsung T-5, the lead tug, was to adjust at will, the length of the towing wire, depending on the situation. But not only was the towing wire of Samho T-3, which had a relatively weaker bollard pull, longer in length, but the check list also unreasonably specified that a stretcher for impact absorption be connected. But Master of Samsung T-5 did not object this and jointly signed with the inspector, the towing insurance certificate. When extending the towing wire to commence full coastal navigation, he did not care at all in using steel wire ropes on both tugboats and in extending the towing wire of Samsung T-5, which had better bollard pull, by approximately 20 m. ([Diagram 12], [Diagram 13])

Master of Samsung T-5 adjusted the gyro course to 202°, when the ship got pushed over to the starboard side at around 21:30. And while the sea was calm and there was a mild Southwest wind of Beaufort Scale 3 blowing from the bow, the towing fleet cruised at approximately 208° without much difference from the 206° of the intended course. It continued to sail without listening to the Daejeon Regional Meteorological Administration's broadcasting at around 22:40, announcing gale warning in the far seas of the Yellow Sea.

3.1.1.3. Decline in course keeping ability due to exposure to heavy seas of the outer sea

At around 23:30, from the point the towing fleet passed Uldo Island located on the southern tip of Deokjeokgun-do at a distance of approximately 3.3 miles from the starboard side, heavy seas from the outer Yellow Sea pushed the ship over to the port side by approximately 20° from its intended course of 206°, to approximately 186°.

But the Master of Samsung T-5 was not aware of the fact, sailed the gyro course of 202° at an average speed of approximately 3.5 knots, handed navigational watch over to Chief officer, and then went to bed. ([Table 8], [Diagram 18])

3.1.2. Deviation by reducing bollard pull due to adverse weather

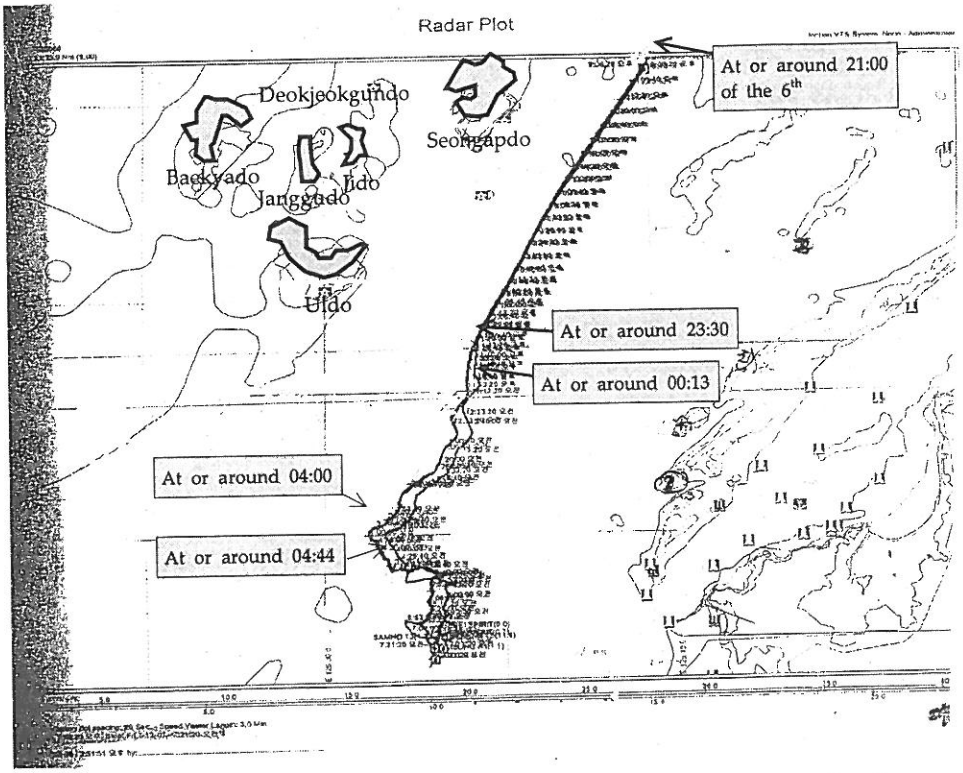
(around 00:00 to 04:00 of 7 December 2007) ([Diagram 18].[Diagram 19])

When navigational watch was handed over from the Master of Samsung T-5 to its Chief Officer, the towing fleet was already exposed to strong wind and wave from outer sea that it was pushed over toward the port side severely, but continued to sail leaving a track of a ship course of approximately 186°.

But the Chief Officer did not realize it. From 00:13 on December 7, the ship changed to auto steering, that there was severe yawing of the bow's direction and the speed began to drastically drop by approximately 2 knots. A large crane barge, Samsung No. 1, was pulled by approximately 400 meters of towing wire and towed at dead-slow speed, when it began to drift away separately from the tugboats' course direction, influenced by strong wind and wave coming from the starboard side. The entire towing fleet progressed at approximately ship course of 210° along the intended course. But it began to zig zag extremely unstably, that the Chief Officer changed the ship's course to 230° at around 03:30.

While the tugboats progressed on a gyro course of 230°, the actual track progressed at direct ship course was approximately 210°, that he thought it was sailing without much difference from the intended ship course of 206°, and he said through VHF

channel 15 to Samho T-3, "…we are sailing unto 230° because of bad weather. But actually, we are on the right course…," indicating that he did not seriously realize the towing fleet's zig zagging. ([Diagram 18], [Diagram 19])



[Diagram 18] At around 23:30, approximately 30 minutes before the hand-over of navigational watch by the Master of Samsung T-5 to its Chief Officer, the ship was about to pass Uldo Island, when the tugboats began to drift South, and thereafter, the track of the towing fleet began to be seriously unstable.

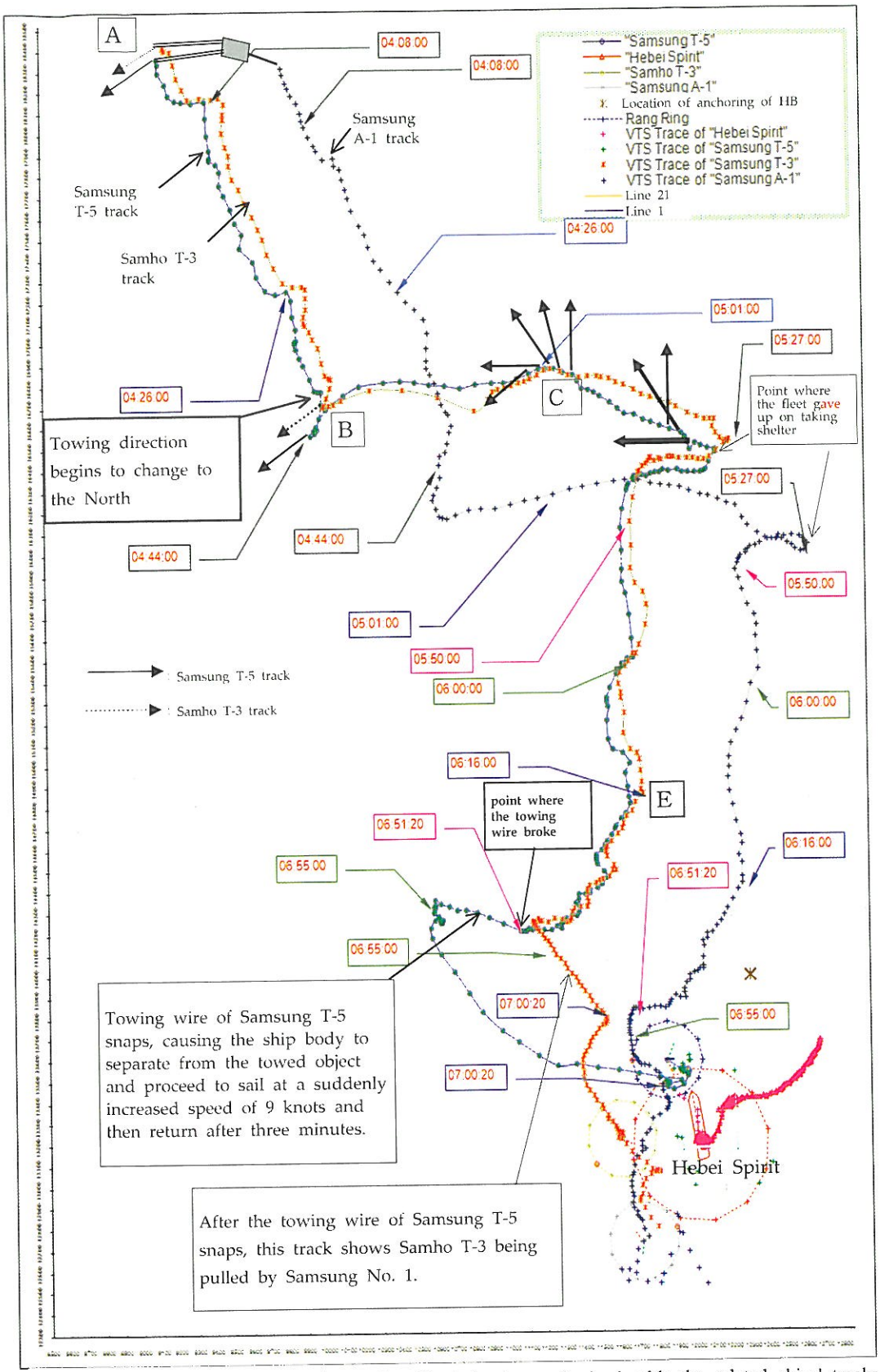
At about 04:00, the fleet manager of Samsung No. 1 asked the Chief Officer of Samsung T-5, "…is it safe to navigate?", to which he heard the answer that "it is safe." However, this is when the Master of Samsung T-5 was reported by the Chief Officer, that the fleet encountered bad weather. The Master of Samsung T-5 therefore went up the bridge to find out that the speed had dropped by approximately 1.7 knots with the tugboat's towing ability greatly weakened and the tugboats severely pushed over. He decided to take shelter at a suitable place toward Incheon Port, because normal navigation was impossible.

Master of Samsung T-5 did not have any place set, before departing Incheon Port, for taking shelter in case of an emergency if he encountered bad weather during

navigation. And although the voyage recommendation of the towing test required that he immediately inform the ship owner and towing inspector in case of any deviation or problem on the towing fleet in order to be notified of immediate action to be taken, he did not act accordingly. Instead, he took independent action on his own, that he could not get any external cooperation for safety action by having authorized agencies, such as the VTS Center in the area and others, announce early a warning to the ships nearby. ([Diagram 19])

3.1.3. Attempt to take shelter - giving up taking shelter - attempt to return to the intended course (At round 04:00 to 05:17 of 7 December 2007) ([Diagram 19])

While the towing fleet was seized by heavy weather at around 00:00 the same day and sailed zig zagging, it maintained the intended course with a track of approximately 210° overall. However, from around 04:00, the weather got very worse, that the fleet prepared to take shelter toward Incheon Port by reducing the speed, when its passed track changed by almost 90° from SW to SSE. The ship rapidly drifted for approximately 1 mile without any resistance([Diagram 19], from "A" to "B"). From around 04:44, the tugboats' bow direction slowly turned right, and the towing fleet began to be pushed over to the East again. (Point "B" in [Diagram 19]).



[Diagram 19] This diagram has the towing fleet's tracks synthesized with the related ships' tracks as shown on the radar screen of the VTS Center of Daesan Port and information provided by related people's statements.

Despite the fact that several large ships and an very-large crude carrier, Hebei Spirit, loaded with crude oil, were anchored at approximately 2 miles Southeast of the towing fleet's track sailed from 04:00 to 04:44, the Master of Samsung T-5 did not inform about its dangerous situation to the nearby VTS Center or to any other ships. And right after 05:00 (Point "C" in [Diagram 19]), the towing fleet continuously got pushed over to the East, even after changing the gyro ship course to 000° over for several minutes toward Incheon Port (From point "C" to point "D" in [Diagram 19]). Even if Master of Samsung T-5 changed the tugboats' ship course to 000°, in order to take shelter toward Incheon Port, Samsung No. 1 did not get pulled, and heavy seas kept pushing it to the East.

Instead, Samsung No. 1 pulled the tugboats, that Master of Samsung T-5 gave up sheltering at around 05:17. The Master of Samsung T-5, vaguely concerned that the anchorage made of sand could not have holding power, decided to sharply turn left with a ship course of 270°. He then began to pull Samho T-3 to the direction of the initially intended course. Observing this abnormal movement, VTS Center felt suspicious of the towing fleet's track that it called Samsung T-5 and Samsung A-1 at around 05:23 through VHF channel 16, but did not get any response, because they were unable to hear it. (Between point "C" and point "D" of [Diagram 19])

At this time, Hebei Spirit was anchored, with heading of approximately 340°, at approximately 190° and approximately 1.7 miles from the towing fleet. From Hebei Spirit, Samsung No. 1 was at sight at approximately 25° of the ship's head on the starboard side.

3.1.4. While attempting to return to the intended course, the towing wire snaps and the ships collide (Around 05:17 7 December 2007 - 07:06)

3.1.4.1. Master of Samho T-3 gets on the bridge (around 05:30)

The Chief Officer of Samho T-3 learned of the seriousness of the situation after receiving instructions from Master of Samsung T-5 of Samsung T-5 to give up taking shelter and return to the original route. He then woke Master of Samho T-3 up, who

was sleeping after duty, with an amplifier at about 05:30. At this time, Master of Samho T-3 got on the bridge and it was only then that he realized the towing fleet had lost its towing ability and was in a dangerous condition. (Immediately after passing the point "D" of [Diagram 19])

Although the Master of Samho T-3 was aware of the dangerous situation, he did not suggest emergency anchoring to the Master of Samsung T-5 or propose to inform of risk to other ships around. He failed to undertake the role as the Master of the assist tug and continued navigation under the command of the Master of Samsung T-5.

3.1.4.2. Towing fleet communicates for the first time with the VTS Center (06:17) and realizes Hebei Spirit's presence (06:27)

The towing fleet had been drifted South and approached Hebei Spirit. Around 06:14, when the distance narrowed to approximately 0.5 mile and Hebei Spirit recognized risk coming, it called Samsung T-5 and Samsung A-1 through VHF channel 16, but did not get any response.

At the request of Hebei Spirit, the VTS Center of Daesan Port first contacted the Master of Samsung T-5 on his mobile phone at around 06:17 and the fleet communicated for the first time with people outside the fleet. (Around point "E" of [Diagram 19])

Only after barge Samsung No. 1 had already approached up to approximately 0.5 mile from Hebei Spirit's bow, which was directed almost straight North, the Master of Samsung T-5 informed the VTS Center of Daesan Port that normal navigation would be difficult due to bad weather. The VTS Center informed the said fact to Hebei Spirit after 10 minutes at around 06:27.

3.1.4.3. Towing fleet and the VTS Center repeatedly requests Hebei Spirit to move away

About 2 minutes later, at around 06:29, although Samho T-3 along with Samsung T-5 continued to tow toward 270°, Samsung No. 1 drifted and closed into approximately 260 m from Hebei Spirit's bow (the distance from the bridge by radar observation was approximately 3 cables (approximately 540 m). [Diagram 15].

Master of Samho T-3 called Hebei Spirit through VHF and said, "your ship is being dragged…," when he saw that Hebei Spirit had already slackened its anchor chain and was moving backward to widen the distance between the two ships. Approximately one minute later, at around 06:30, it called again to request that Hebei Spirit move away by heaving up its anchor and operating the main engine, in order to avoid the collision. It changed course to approximately 300° together with Samsung T-5 to widen the distance between the two ships.

At the same time, VTS Center of Daesan Port also repeatedly asked Hebei Spirit to operate the main engine, move with the anchor heaved up and to take action for utmost safety in order to prevent a collision.

3.1.4.4. The towing wire of Samsung T-5 snaps and Samsung No. 1 drops anchor but collides with Hebei Spirit

At around 06:30, the bow of Samsung No. 1 crossed from the starboard side to the port side of Hebei Spirit's bow, which was headed straight North. At around 06:40, as Samsung No. 1 reached the closest point of approach (CPA) of approximately 0.3 mile and approximately 345° from Hebei Spirit, Master of Samsung T-5 worried of the high risk of collision, towed at maximum output power. At 06:52, Samsung T-5 towing wire had to bear the ship's weight under waves, which led to excessive tension and the wire broke at approximately 50 meters from the stern at the rear.

With the towing wire broken, Samsung T-5 separated from Samsung No. 1 and its speed suddenly surged to approximately 9 knots, that it moved forward to approximately 300°. Master of Samsung T-5, who realized from the breaking noise that the towing wire had broken, drastically turned the ship to 130° at around 06:54, to turn it back toward Samsung No. 1, and contacted Fleet Manager through VHF and said, "…towing wire snapped and you should take emergency measures…".

As soon as receiving instructions for emergency action from Master of Samsung T-5,

Fleet Manager immediately instructed boatswain to prepare dropping anchor. Boatswain led two crews to the poop deck to loosen the stopper and windlass brake, and thus finished to prepare for anchoring. He then reported it, upon which he was immediately instructed to drop anchor. Thus, he dropped the anchor on let go at around 07:00, approximately 6 minutes before the collision. Approximately 6 minutes had lapsed since the Master of Samsung T-5 had instructed to drop the anchor.

In the mean time, at around 06:52, immediately before Samsung T-5's towing wire snapped, the VTS Center of Daesan Port called Hebei Spirit through VHF to inquire again if the ship could move, as the distance between Samsung No. 1 and Hebei Spirit did not widen at all. But Hebei Spirit replied that it was impossible.

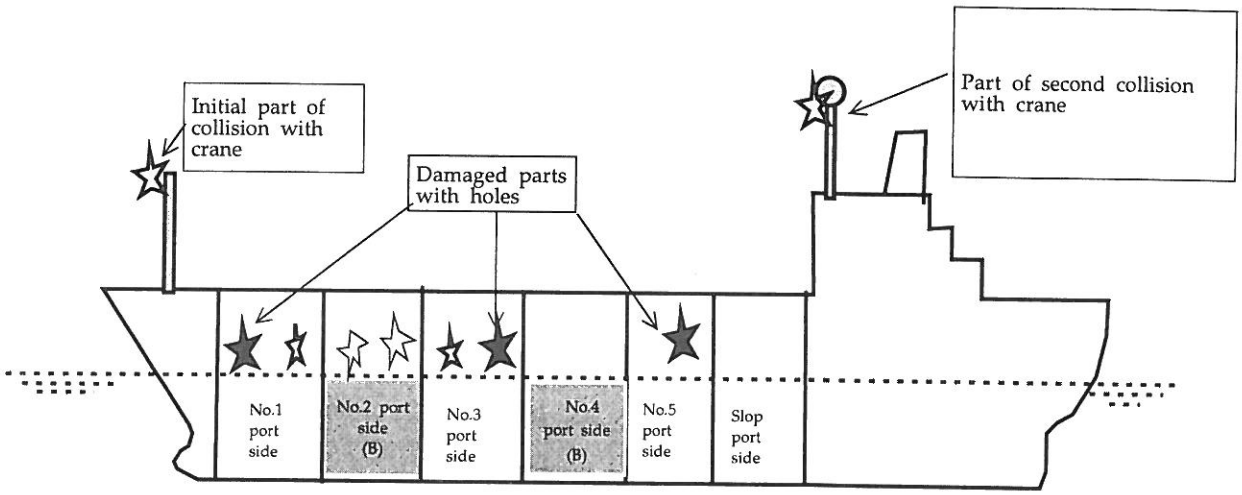
Samsung No. 1, whose towing wire from Samsung T-5 snapped, did not have enough practical bollard pull, with only the towing of Samho T-3. It therefore rapidly drifted toward Hebei Spirit. Master of Samho T-3 and Master of Samsung T-5 informed the VTS Center of Daesan Port at 06:55 and 06:57, respectively, that Samsung T-5's towing wire had snapped, that collision between Samsung No. 1 and Hebei Spirit was impending, and that normal towing was impossible. Therefore, the VTS Center of Daesan Port requested again to Hebei Spirit at around 06:58, that it move by heaving up anchor and using the main engine.

After dropping the anchor in emergency, Fleet Manager had the bosun continuously lay out the anchor chain. The anchor of Samsung No. 1 gained substantial holding power, that the barge proceeded at a very slow speed of 1～2 knots. Then, at around 07:06 of 7 December 2007, at Latitude 36°52'16"N and Longitude 126°03'02"E, or at 253° and approximately 5 miles from the Sindotaseo lighthouse in Wonbuk-myeon, Taean-gun, South Chungcheong Province, Republic of Korea, the hook at the end of Samsung No. 1's crane boom first collided with the upper part of Hebei Spirit's fore mast. ([Diagram 20])

Later, at around 07:13, the port bow of Samsung No. 1 collided at approximately 30° with the upper part of the hull plate bow on the side of Hebei Spirit's cargo tank no. 1(port), making a hole that began leaking crude oil. Thereafter, Samsung No. 1 kept

drifting toward Hebei Spirit's stern side, while continuing to touch the hull plate of the port side, colliding 8 more times in total. As a consequence of the collisions, holes resulted on cargo oil tanks no. 3 and no. 5, both on the port side, adding up to three holes in total, with substantially more oil beginning to leak into the sea. ([Diagram 20]. [Table 8])

After the initial collision between the two ships, Fleet Manager checked to find out that approximately 5.5 shackles (approximately 151m) of Samsung No. 1's anchor chain had been laid out. Thereafter, it kept slacking with 12 shackles from a total of 14 shackles (approximately 330m) being laid out.



[Diagram 20] Damaged parts on Hebei Spirit from the collision. There were a total of 9 collisions that caused three holes. The areas shaded in gray are ballast water tanks.

[Table 8] Sizes of three holes on Hebei Spirit

Tank number	Distance from upper deck line to damaged holes (m)	Size of the damaged (mm) (length x width)
1 (p)	Approximately 5.3	300 x 30
3 (p)	Approximately 7.8	1,200 x 100 (maximum value)
5 (p)	Approximately 7.2	1,600 x 2,000

In addition, the upper structure of no. 3 port side cargo oil tank and no. 4 port side ballast water tank of Hebei Spirit got damaged from the impact of the collision, that

approximately 326 kilo-liters (approximately 283 tons) of crude oil loaded in the no. 3 port side tank spilled into the no. 4 ballast water tank.

In the meantime, as a result of the collision, Samsung No. 1's port side bow edge got bent by about 340cm.

At the time of the accident, there was a strong NWN wind blowing at 15～18 meters per second (Beaufort Scale 6-7), wave height of 4 meters, a Southwest tide of approximately 2 knots, and good visibility.

3.2. Hebei Spirit

3.2.1. Arrival at the coast of Daesan Port and anchoring

Hebei Spirit loaded crude oil of a total of approximately 263,944.5 tons at four ports of Mina Al Ahamadi and Kafuji of Kuwait, Kharg Island of Iran and Zirku Island of the UAE. A total of 27 crew members (6 Indians, 16 Filipinos, 5 Chinese), including Indian Master and Indian Chief Officer, were embarked. It departed from Zirku Island, UAE, at 10:42 on 16 November 2007, and headed to Daesan Port in South Chungcheong Province in the Republic of Korea.

Before departing from port after loading crude oil at the four loading ports, there was a replacement of Chief Officers. Upon completion of final loading at Zirku Island, UAE, and while receiving the fuel oil, Chief Officer went on board to complete the hand-over from his predecessor, and the predecessor disembarked.

After departing from Zirku Island Port, the ship went along the intended course to pass the Indian Ocean and the East China Ocean and approached the Daesan Port area in the afternoon of 6 December 2007. It then received information through VHF channel 12 from the VTS Center, to wait outside Daesan Port. Hebei Spirit anchored near the intersection of the northern access of the traffic separation scheme (TSS) of Heukdo Island and the access route to Daesan Port and Pyeongtaek Port.

In spite of the fact that this could obstruct coastal traffic, the Master anchored the ship at around 19:18 (local time) of December 6, without further reviewing navigation safety, at 255° and approximately 4.8 miles from the Sindotaseo lighthouse in Wonbuk-myeon, Taean-gun, or Latitude 36°52'29"N and Longitude 126°03'14.5"E. He thus decided this at his own will based on his previous entry into Daesan Port on October 13 of the same year, when he anchored nearby.

After anchoring, Master of Hebei Spirit changed the on-duty system from navigational watch to anchor watch, despite a forecast warning of bad weather from dawn the following day. Hebei Spirit was scheduled to berth on SBM (Single Buoy Mooring) in order to discharge its cargo the following day. The pilot of Daesan Port was scheduled to board the ship at around 14:00 the following day.

Master of Hebei Spirit stopped the engine and informed Chief Engineer that he would give a one-hour-notice before using the main engine. Under such circumstances, the Chief Engineer began to change the exhaust valve of the main engine's no. 3 cylinder, which normally requires 3～4 working hours. He completed the change at 23:55. Upon completion, he did not reopen the cooling water valve of no. 3 cylinder, which he had closed for the change, such that the main engine was left unusable under normal conditions.

At the time of anchoring, a heavy seas warning in the far seas in mid Yellow Sea, with a WNW wind of 12～16m per second and wave height of approximately 2～4m, was forecast for 03:00 the following day. At that time, there was a NE wind of Beaufort Scale 3 and approximately 2 knots of SW tidal current, and the ship was headed toward the wind at approximately 70°. A red light to indicate hazardous substance load and an anchoring light were turned on. Nearby, in the east and Northeast, there were other ships anchored at a distance of 2 miles.

3.2.2. Anchor watch (Around 19:18 of 6 December 2007 - Master came on the bridge at around 06:06 the following day)

Hebei Spirit was under anchor watch after anchoring and a Third Officer with one deck crew began anchor watch on the bridge. The Master went up the bridge again at around 21:15 on December 6, to prepare the night order book, which instructed the officers to call the Master in case of any doubt and went to sleep to his room.

At around 04:00 on December 7, Chief Officer of Hebei Spirit, who was on the bridge for anchor watch, handed over the watch to a Chinese apprentice officer, who was not familiar with ship operation practices. There was then no qualified seaman to watch properly on the bridge, while the weather got worse. The Chief Officer then worked on other matters that he was not able to make any systematic observation of the surrounding ships with the ARPA radar.

Therefore, anchor watch was not being actually performed and there was no one on the lookout, that no one realized how, at only 3 miles toward its bow headed to approximately 310°, there was Samsung No. 1 - with several blindingly bright lights, including lights for work, turned on its deck - being towed by two tugboats forming a towing fleet of a total of about 730m in length, drifting toward Hebei, having lost towing capacity under the rough weather.

From around 04:00, the weather got worse, with a West wind of Beaufort Scale 7 and 4 meter wave height. In the midst of this, only apprentice officer stayed on the bridge on behalf of Chief Officer of Hebei Spirit, and he did not realize the seriousness of the situation, despite the following: the fact that Hebei Spirit was slowly yawing on both sides; the towing fleet was drifting SSE toward Hebei Spirit for approximately 50 minutes, as explained earlier, and changed course by approximately 90° to the east from 04:50; and at around 05:30, the biggest among the fleet, barge Samsung No. 1, approached at 20° and up to 1.5 miles, from the starboard bow of Hebei Spirit, which was headed to approximately 345°; and the towing fleet continued to navigate abnormally, bearing risk of an collision accident.

Apprentice Officer could have seen the three ships of the towing fleet, namely Samsung T-5, Samho T-3 and Samsung A-1, shown on the radar using AIS (Automatic Identification System). But he neglected the lookout and did not properly

assess the collision risk, that he did not take measures, such as calling the fleet early through VHF or asking the VTS Center, nor properly report to Chief officer on the danger of a serious collision.

Until then, despite the fact that the tugboats' bows were headed North, the fleet as a whole drifted almost East But from about then onward or 05:30, the tugboats changed course to the left and headed 270°. Yet, the towing fleet drifted South again toward Hebei Spirit's bow. As a result, at around 06:00, the fleet approached at 1.5 knots and up to 1.0 mile, the bow of Hebei Spirit, which was then headed toward approximately 345°.

It was only then that the apprentice sensed danger and reported to the Chief officer of Hebei Spirit that the towing fleet had approached Hebei by approximately 1 mile and approximately 0.3 mile CPA. Then, the Chief Officer sensed the risk of collision and reported the seriousness of the situation to the Master at around 06:05.

3.2.3. Actions taken by Master of Hebei Spirit to avoid collision (Around 06:06 on 7 December 2007 to 07:06)

3.2.3.1 First recognition of towing fleet by Master of Hebei Spirit and his understanding of the situation

When Master of Hebei Spirit went up the bridge at around 06:06, after having been reported on the phone that the towing fleet was approaching Hebei Spirit, he saw how Samsung No. 1 was headed toward her port bow at within 20° of her starboard bow and 0.7 mile off heading to 340° with blindingly bright lights for work turned on and was being pulled by two tugboats. It was then that he recognized Samsung T-5's port side red light and three white lights turned on for towing, and Samsung A-1's port side red light. But discerning Samsung No. 1's sailing light was impossible because of the lights lit on the deck for work.

With the ARPA radar, Master of Hebei Spirit attempted to confirm the towing fleet's moving situation by measuring from Samsung No. 1, and realized that a towing fleet of about 730 m had its bow headed West, while it was actually moving South and

sailing across its bow and going down slanted toward his ship's port side at approximately 1.5 knots. Therefore, he predicted the fleet would pass through the port's beam at CPA of approximately 0.3 mile.

3.2.3.2 Master of Hebei Spirit confirms the towing fleet's presence, while trying to avoid it by using the main engine dead slow astern

After having grasped the towing fleet's movements, Master called the VTS Center of Daesan Port through VHF channel 12 at around 06:09, to inquire about the towing fleet's identity. But the Center asked the Master to wait because it had also failed to communicate through VHF with the tugboats.

Thereafter, Master of Hebei Spirit asked the chief engineer on the phone at around 06:10 that he prepare the main engine for use. In order to widen the passing distance from the towing fleet, which was increasingly approaching his ship from forward. The Master ordered Chief Officer to go forecastle and prepare to slacken its anchor chain.

The Master also called Samsung T-5 and Samsung A-1 at around 14 minutes of the same hour through VHF channel 16, but did not get any response. Upon being reported that the main engine was ready for use at around 06:17, he instructed the Chief Officer of Hebei Spirit on the forecastle to slacken the anchor chain by operating the main engine dead-slow astern.

Thereafter, when the Master operated the main engine stop and dead slow astern repeatedly, and had slackened the anchor chain more to 13 shackles on deck, he was contacted by the VTS Center at 06:27, informing him that the towing fleet was having difficulties in controlling and was being carried away. At around 06:29, Master of Samho T-3 contacted Hebei through VHF channel 16 when he saw that Hebei Spirit was back pedalling, and said, "your ship's anchor is dragging...".

3.2.3.3 Collision while dragging the anchor and repeated requests to heave up anchor were made by the VTS Center and the towing fleet

At 06:30 the same day, Master of Hebei Spirit was requested by Master of Samho T-3 to move the ship by heaving up the anchor, and was repeatedly requested the same and to take maximum safety measures by the VTS Center. But its anchor chain had already been slackened up to 13 shackles with only some spare left. And barge Samsung No. 1 was crossing his ship toward the port side at some 300 meters from his ship's bow, that he was concerned his ship's body would move forward toward Samsung No.1 and collide with it, if he hove up the anchor chain. So he informed the VTS Center that it was impossible to heave up the anchor and move.

While Master of Hebei Spirit was using the main engine repeatedly dead slow astern and stop, Samsung No. 1 crossed Hebei Spirit's bow at around 06:32. And at around 06:40, it passed Hebei Spirit's port side with CPA of about 0.3 mile when her heading was 340°.

Master of Hebei Spirit waited for the towing fleet to pass the CPA and move away, when he was asked a second time by the VTS Center at around 06:52 whether he could heave up the anchor and move away. At around 06:54, he saw how Samsung T-5 protruded forward, its towing wire having snapped, and then returned toward Samsung No. 1. But he did not know it was because its towing wire had snapped.

As Samsung No.1 again approached Hebei Spirit, its towing wire having snapped, the VTS Center repeatedly requested Master of Hebei Spirit at around 06:57 to heave up the anchor and move away. As it became urgent, the Master repeatedly tried to use the main engine slow astern and half astern at 06:58 and 06:58:30, respectively, but the high temperature alarm of the engine's no. 3 cylinder C.F.W. outlet rang and the main engine's RPM automatically slowed down. Therefore, the main engine became uncontrollable. He then informed the VTS Center that "...this ship has a slight problem that it is difficult...".

Master of Hebei Spirit did not take any emergency measures while the main engine did not respond to control, when Samsung No.1 drifted to the bow, that he felt the danger of impending collision. At around 07:00, he instructed the Chief Officer of Hebei Spirit to slip the anchor chain by dismantling the chain's end link (bitter end)

from the ship. When the main engine became operable again from around 07:04:30, he used the main engine to move dead slow astern, slow and dead slow astern, then half astern.

However, notwithstanding such measures, Hebei Spirit collided with Samsung No. 1, as described earlier, at 07:06, without having dismantled the anchor chain's end link from the ship.

After the collision, as Samsung No. 1 made holes on Hebei Spirit's port side hull plate and drifted further down toward the stern, the Master of Hebei Spirit used the hard port rudder and the forward engine at dead-slow speed at around 07:21, to prevent holes from being made on the engine room's port side hull plate. He succeeded by causing the stern kick, but the stern moved to the starboard side and Hebei Spirit's upper mast bridge collided with the hook at the end of Samsung No. 1's crane boom, damaging the satellite antenna and interrupting satellite communication with the outside for approximately 6 hours.

Then, at around 07:28, he went out to the port side wing deck upon being reported that cargo oil was leaking, and confirmed leakage of cargo oil from port side cargo oil tanks no. 1, no. 3 and no. 5.

3.2.4. Action taken to reduce the cargo oil leakage

Master of Hebei Spirit rang the general alarm immediately before the hook at the tip of Samsung No.1's crane boom first collided with Hebei Spirit's fore mast and gathered the crew before the life boat in accordance with the emergency muster list. And upon being reported that cargo oil was leaking, he reported through VHF the oil pollution to the VTS Center.

Thereafter, Master of Hebei Spirit did not take any action to prevent cargo oil from leaking despite there being no serious threat to Hebei Spirit's safety, as damage to the ship was minor and the shock was not significant. The Master instructed the Chief Officer of Hebei Spirit to carry out ullage and sounding check for all cargo tanks, the ballast water tank, void space, and engine room. As the

leaked cargo oil blew under heavy wind, the deck became slippery and oil splattered unto to the crew. The work was completed at around 09:45. As a consequence, he did not take any measure to prevent the cargo oil leakage for almost three hours.

At around 09:38, when the sounding task was almost finished, an officer of the Korean Coast Guard landed on Hebei Spirit through a helicopter. Upon having consulted with the officer, Master of Hebei Spirit only then began to install collision mats on the holes on the port side cargo tanks no. 1 and 3, to stop the cargo oil leakage. Despite the fact that the damaged cargo tanks' pressure had to be lowered by separating and sealing off all pipes connected to the tanks to suppress the oil leakage, he was overly concerned with the risk of an explosion, that he instructed Chief Officer of Hebei Spirit to start the IGS (Inert Gas System) at around 10:00 and blew inert gas into all cargo oil tanks, including those leaking oil.

Master and Chief officer of Hebei Spirit started the no. 2 cargo oil pump of 4,500m^3 per hour pumping capacity, and began to transfer cargo oil from port side cargo tanks nos. 1 and 3 to center cargo tanks nos. 3 and 5, which had relatively more storage space, at around 10:35, about three and half hours after the first cargo oil leakage. Thereafter, they attempted to transfer it to the storage space in center cargo oil tanks nos. 1, 2 and 4 and starboard side cargo oil tanks nos. 3 and 5. From 11:15, they filled in approximately 3,000 tons of sea water into the starboard side ballast water tank in order to heel the ship to approximately 5° toward the starboard side, and worked on transferring cargo oil into other cargo oil tanks until 11:45.

The ship's port side cargo oil tank no. 5 finally stopped leaking cargo oil at around 12:00 on December 7, the port side cargo oil tank no. 3 at 16:00, and port side cargo oil tank no. 1 at 23:40 on December 8, each. As a result, a total of 12,547 kilo-liters (approximately 10,900 tons and approximately 78,918 barrels) of crude oil leaked, causing a major oil pollution accident that seriously polluted the western coast of the Republic of Korea. ([Table 9])

Temporary emergency measures were taken on Hebei Spirit to stop further cargo oil leakage at around 07:00 on December 9 or around 48 hours after the collision. Master of Hebei Spirit then reported to the Korea Coast Guard Agency that crude oil leakage had stopped.

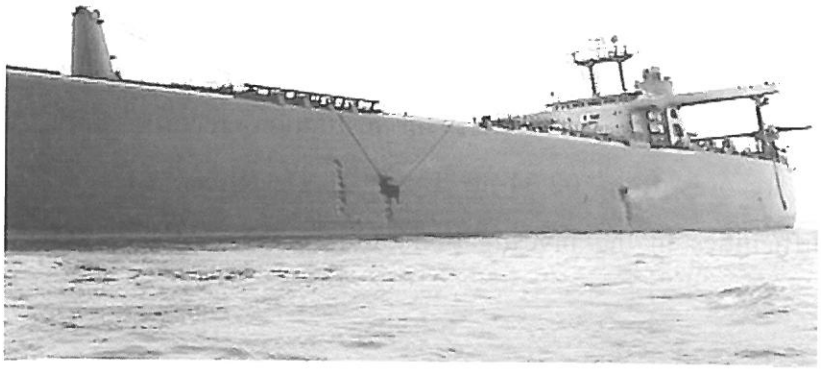
3.2.5. VDR

In the event of a marine accident, such as a collision, the Master must save the VDR data immediately, and only the investigator of concerned authorities can investigate the VDR evidence data. After the accident, Master of Hebei Spirit had to immediately save the VDR data installed on Hebei Spirit, but he did not save it and left it at bay. On the day following the accident, at around 15:34 on December 8, P&I surveyor saved the data by belatedly pressing the save button with Master of Hebei Spirit's consent. Master of Hebei Spirit admitted that the P&I surveyor had taken out the VDR backup disc at around 09:00 on December 10, without any permission from relevant authorities upon instruction by the lawyer working on behalf of the P&I Club.

Upon request from the Korea Coast Guard Agency, the surveyor submitted the disc to the coast guard on December 16. Thereafter, when the backup disc data were analyzed under the presence of a relevant institution, records during the accident were missing. Only records from 02:34 to 15:34 of December 8, were found. This caused substantial difficulties in the investigation of the causes of the said marine accident.

[Table 9] KOMSA calculation of cargo oil leakage volume carried out after the accident on 9 December 2007

Measurement period	Bbls	K/L	M/T
(A) Load volume (port side before departing the final shipping place)	1,903,553	302,640.780	263,944.577
(B) Load volume (starboard side at the time of entry to Daesan Port after the accident)	1,799,328	286,070.327	249,544.411
(C) Transferred volume (to the barge at Daesan Port after the accident)	25,307	4,023.492	3,500.144
Difference (release volume) ((A)- (B) -(C))	78,918	**12,546**.961	**10,900**.022



[Diagram 21] Damaged holes on cargo oil tanks nos. 3 (port) and 5 (port) of Hebei Spirit (vapor leakage after the oil leakage)

[Table 2-1]

Loaded cargo volume of Hebei Spirit at the time of departing from the loading port

Cargo oil tank	Name of loaded cargo oil	Tank capacity (BBLS)	Loaded volume (before calibrating temperature)				Loaded volume (after calibrating temperature)	
			BBLS	%	API	Temp. (°F)	BBLS	%
1C	KCO	199086	195210	98.05	28.2	84.9	193082	96.98
2C	KECO	164648	161319	97.98	30.7	94.5	158819	96.46
3C	IHCO	211691	203457	96.11	29.7	89.4	200792	94.85
4C	KCO	164648	161709	98.21	28.2	84.7	159979	97.16
5C	UZCO	239438	224557	93.79	31.24	87.1	221817	92.64
1S	UZCO	140049	136173	97.23	33.2	87.1	134471	96.02
3S	KECO	187588	183691	97.92	30.7	92.8	180972	96.47
5S	IHCO	140056	137253	98.00	29.7	88.0	135551	96.78
SS	KECO	34717	34147	98.36	30.7	95.7	33563	96.68
SP	KECO	34717	33940	97.76	30.7	97.9	33397	96.20
Line Content			(-)465			87.1	(-)459	
Subtotal		1516638	1470991	96.99	30.19	88.95	1451984	95.74
1P	UZCO	140049	135802	96.97	33.2	87.1	134104	
3P	KECO	187588	184037	98.11	30.7	92.7	181350	
5P	IHCO	140056	137416	98.12	29.7	88.0	135712	
Subtotal		467693	457255	97.77			451166	96.47
Total		1984331 (315,483.5㎥)	1928246 (306,567.0㎥)	97.17	30.4	89.1	1903149	95.91

[Table 2-2] Calculation of expected cargo tank spare capacity not damaged at the discharging port

	Cargo volume at the measured temperature (Bbls.)	Spare capacity (Bbls.)	Average measured temperature (°F)	Cargo volume at standard temperature (Bbls.)
(A). Load volume (port side before departing from the final loading area)	1,470,991	45,647 (96.99%)	89.1	1,451,984 (230,842.22K/L)
Average measured temperature at the time of entry to Daesan Port after the accident			65.9	
(B). Expected cargo volume at the time of entry to Daesan Port after the accident	1,455,716	60,922 (95.98%)		
(C). Total capacity of cargo tank not damaged	1,516,638	-	65.9	1,512,755 (240,509.24K/L)
Expected spare capacity ((C) -(B))	60,922		VCF: 0.99754	60,772 (9,661.78K/L)

* VCF: 0.99754
(From Table 6A, it is calculated on the basis of average API 30.19 and temperature of 65.9)
** Expected spare capacity prior to the accident;
- From the measured temperature; **60,922 Bbls = 9,685.46** ㎥, - From the standard temperature; 9,661.78K/L

4. Causes

This accident is applicable to Article 2 (i) (B), (D), and (E) of the "Act on Investigation and Inquiry into Marine Accidents." Marine pollution caused by the collision requires disclosing separately, the cause of the collision and the cause of marine pollution by nature of the accident.

It is possible to examine closely the cause of the collision by analyzing focused on the appropriateness of measures taken and compliance to relevant regulations for navigational safety and collision avoidance by both the towing fleet and Hebei Spirit; and the cause of oil pollution by analyzing focused on whether mass oil leakage, which caused large-scale oil pollution, happened because of inevitable circumstances

from the collision or because of idle response even if it could have been reduced if reasonable care had been taken.

Therefore, the following analysis and judgement of the causes will be divided into collision and marine pollution. And since a substantial part of these accidents are indispensably linked with personal negligence, they will be examined by classifying them again into the factors that provided the causes.

4.1 Causes of the collision

4.1.1. Navigational rules to be applied

4.1.1.1. The towing fleet's status under navigational rules

According to the analysis of the towing fleet's towing ability and track, when the towing fleet was exposed to rough seas, it was posed to a situation where the bollard pull became almost the same as the external forces or the latter became stronger so that the towing fleet pulled Samsung No. 1 against external forces at some point. But once the bollard pull was unable to overcome the external force, because of stronger wind and wave or added dynamic weight, it was actually being pulled by Samsung No.1. This repeated until the external force surpassing the bollard pull repeated often, that following the intended route became impossible.

In analyzing the cause of the collision, let alone whether the tugboats are to be censured because they did not have enough towing ability to resist the weather condition at the time or they missed the opportune moment to deviate in order to take shelter, it is necessary to check what Samsung T-5 and Samho T-3 should have done according to the International Regulations for Preventing Collisions at Sea, 1972 (COLREG) and Korean laws.

According to the definition in Article 2(7) of the Sea Traffic Safety Act, the "Vessel not under command" means a vessel which through some exceptional circumstance is

unable to manoeuvre as required by these Rules and is therefore unable to keep out of the way of another vessel. According to Article 2(8), "Vessel restricted in her ability to manoeuvre" means a vessel conducting work, such as the installation of navigational aids, underwater operations, and so on, restricting her manoeuvring ability, and is therefore unable to keep out of the way of another vessel.

On the other hand, Rule 3(f) of COLREG defines a vessel not under command as a vessel, which through some exceptional circumstance, is unable to manoeuvre as required by these Rules and is therefore unable to keep out of the way of another vessel - the same as the Sea Traffic Safety Act.

There is no difference in taking the vessel as restricted in her ability to manoeuvre since the towing fleet in this case showed a decent track on true course of approximately 206° of the intended track and thus was not in a situation where their ability to maintain its course is severely restricted before it suddenly encountered rough seas when passing Uldo Island.

However, the situation in which the towing fleet showed extreme serpentine track from the time they passed Uldo Island until 04:00, when they decided to take shelter, shall be considered as a situation whereby the tugboats' ability to keep course is heavily undermined, thereby restricting its manoeuvring ability.

Thereafter, they were drifting South drawing a drift angle of 90° toward Hebei Spirit from the time the tugboats changed their course to 270° at 05:27 in order to return to the original course after having given up taking shelter, until the collision. However, it is unreasonable to consider that the towing fleet was stuck in the middle due to failure of its main engines or steering gear, etc., in light of the fact that the towing fleet was receding from Hebei Spirit, although at a snail's pace, after having passed CPA off Hebei Spirit's port side as it changed course to 300° at 06:30, when it was crossing the Hebei Spirit's bow from starboard to port.

When the main engine or the steering gear is failing; where the holding power is yet to be created after dropping the anchor; where steering is unnatural due to problems within the ship, including dropping the anchor for steering; or where steering is unnatural due to external reasons including "heave to;" when sailing in rough weather or when sailing boat stops without propelling power due to dead calm; in all of the above cases, it is agreeable to consider them as "not under command," but in the case of the towing fleet in the accident, it is not quite agreeable to define it as actually being "not under command."

Because even if at sight they may look as not under command, they were drifting to a direction they did not intend to go. In view of the fact that the fleet could have attempted to avoid the collision by moving to some extent, even though it was moving with a wide drift angle, it would be "a situation where maneuverability is severly restricted" and not "a situation not under command."

Thus, it is common understanding of marine judges that the towing fleet were "vessels severely restricted in their ability to manoeuvre," because it already had severely restricted ability to maneuver from 02:00 on December 7. And from when it gave up on taking shelter until Samsung T-5's towing wire snapped, it should be considered "vessels severely restricted in their ability to manoeuvre to the extent that they were close to vessels not under command."

But, the towing fleet was clearly "vessels not under command" after Samsung T-5's towing wire broke at around 06:52.

4.1.1.2. Hebei Spirit's status under COLREG

Hebei Spirit cannot be considered a "vessel not under command," for it was slackening the anchor chain and dragging the anchor to avoid the collision. It is therefore a "vessel at anchor" under COLREG, since it dragged the anchor to avoid the collision after having dropped 9 shackles of its anchor from the day before the accident.

4.1.1.3. COLREG rules to be applied

In light of its status under COLREG of the vessels involved in the accident, the towing fleet had severely restricted maneuverability and Hebei Spirit was a vessel at anchor. It is proper to apply "responsibility" under Rule 2 of COLREG but not the rules as specified in Part B of COLREG.

Rule 2(a) of COLREG stipulates that "nothing in these Rules shall exonerate any vessel, or the owner, master or crew thereof, from the consequences of any neglect to comply with these Rules or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case." And Rule 2 (b) specifies that "In construing and complying with these Rules due regard shall be had to all dangers of navigation and collision and to any special circumstances, including the limitations of the vessels involved, which may make a departure from these Rules necessary to avoid immediate danger".

Every vessel shall at all times maintain a proper lookout by looking and listening as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of a risk of collision. Every vessel shall use all available means appropriate to the prevailing circumstances and conditions to determine if risk of collision exists. If there is any doubt such risk shall be deemed to exist, proper use shall be made of radar equipment if it has one. Such risk shall be deemed to exist even if the compass bearing an approaching ship does not appreciably change, when the ship is towing.

Also, as in this accident, it includes an obligation to take best steps to avoid collisions by warning risks of collision, conducting an emergency anchoring as well as maintaining a proper lookout thoroughly for the towing fleet whose maneuverability were severely restricted. Therefore Hebei Spirit is obliged to take active steps, including using the main engine to avoid a collision with other ships approaching it that bear a risk of

collision; to maintain the main engine readily usable; and to maintain a proper lookout, while anchored in the open sea.

4.1.1.4. When COLREG rules begin to apply

COLREG, in principle, shall apply from when the risk of collision between the two ships began to exist until it clears. In this case, rules are applicable from about 04:00 of the collision day when the risk of collision emerged as the towing fleet approached at SSE direction, Hebei Spirit, which was 3 miles off.

The rules are not applicable from 04:44 to 05:30, during which the towing fleet proceeded to the East, maintaining 1.5～1.7 miles distance from Hebei Spirit, when no risk of collision existed (during which the towing fleet shall be kept monitored very carefully). Thereafter, from 05:30 when the towing fleet began to proceed toward Hebei Spirit at 1.5 mile (1 hour distance for the towing fleet to reach Hebei Spirit), the rules resumed to apply, and continued to apply when the towing wire snapped after the towing fleet passed the bow of Hebei Spirit, as the risk of collision still existed.

4.1.2. Analysis of towing fleet's contributory factors that caused the collision

To review all factors that contributed to the collision in this case, we analyzed the causal relationship between the collision and each factor including the towing ability, the towing survey and preparation for departure, when taking shelter was attempted, communication with outside the fleet, snapping of towing wire, anchoring in emergency, the navigational rule, and so on. This analysis is mainly about the towing survey.

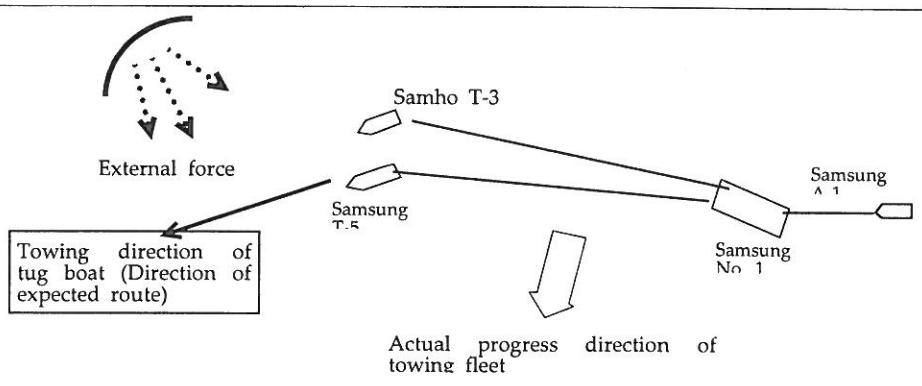
4.1.2.1. Towing ability

4.1.2.1.1. Review of practical towing ability in light of the sailing status at the time of accident.

Towing ability of a tugboat means the ability to sail on intended course surging, swaying and yawing as intended by the ship operator not only on still water but also on external forces, such as waves, wind and tides, when towing another ship. Towing ability depends on the bollard pull of the tugboat and the total resistance imposed on the towed object.

The towing fleet in this case started to sway suddenly when it got exposed to external forces from the open sea, from when it passed by Uldo Island at 23:30, 6 December 2007 (*See* [Figure 18]). From 00:13 on December 7, it almost maintained the intended course of 206° as it swayed between 202° and 210°, but it lost its normal towing ability from about 02:00, as it showed a serious zigzagging track.

When it decided to take shelter by 04:00, the external forces imposed on the towed object Samsung No.1, exceeded the total bollard pull of the tugboats, Samsung T-5 and Samho T-3, such that Samsung No.1 drifted toward the force (the combined vector) of the bollard pull and external forces combined, instead of the direction to which the tugboats were towing Samsung No. 1. Thus, Samsung No.1 pulled the tugboats instead. Because of this, the fleet sidled as the tugboats' towing direction and the actual track of the towing fleet drew an extremely abnormal drift angle of almost 90°. ([Figure 18], [Figure 19], [Figure 3-1])



[Diagram 3-1] About 02:00 of the day of accident, strong external forces pushed the barge over to the port side without pulling from the rear side of the tugboats, which led the fleet to drift at a wide angle and the track to display substantial zig zagging.

This situation means that the tugboats' towing ability had been lost, as the Master of Samsung T-5 could not keep its intended course. As a result, the Master determined to take shelter at around 04:00 on December 7, having decided that keeping the intended course was impossible. This well explains that the tugboats' towing ability was actually lost.

4.1.2.1.2. Analysis on whether the tugboats had towing ability at the moment of the accident

According to the towing approval check list, the bollard pull of Samho T-3 was 46.4 tons and Samsung T-5, 55 tons. However, such figures are based on the maximum bollard pull as mentioned in the test report of the bollard pull produced by Daeseon Shipbuilding Co., Ltd., 12 years before the accident. Taking into account the reduction of output due to long-term operation, the bollard pull of Samsung T-5 at the moment of the accident, shall be taken to be about 48.3 tons, the average bollard pull in the test report, making the total towing ability 94.7 tons.

For the towing fleet to conduct towing normally without being pushed over from the intended course in such rough seas, the total bollard pull shall exceed the total external forces imposed on the barge, Samsung No.1, which is verified by the calculation below.

According to Article 23(3) of "the Standard Structure and Equipment, etc., of Barge," the total resistance imposed on the towing wire is the total resistance imposed on the barge, Samsung No.1, plus additional resistance due to Significant Wave Height ($H_{1/3}$).

As such, total resistance imposed on the towing wire is calculated by

$$R = Rt + Rs$$

R: total resistance, Rt: total resistance put on the barge, Rs: additional resistance due to significant wave height.

And thus, their values under the weather condition of the accident day are as follows:

$Rt = Rf + Rw + Ra$ (in tons)

Rf : frictional resistance, Rw: wave resistance, Ra : air resistance

$Rf = 0.000136 \times F1 \times A1 \times V^2 = 1.42$ tons- - - - - - - - ①

Where, F1 = 0.8 (hull surface coefficient),

A1: wetted surface area (m^2) = (Average draft x ((Length of hull + Width of hull)x 2)) + (Length of hull x Width of hull) = (appox. 3.35 x ((106.6 +45) x 2)) + (106.6 x 45) = 1015.7 + 4797 = 5,812.7 m^2

V= approximately 1.5 knots (towing speed at the moment of the accident), 7 knots if towing speed is unknown.

$Rw = 0.014 \times C \times F_2 \times A_2 \times V^2 = 6.97$ tons - - - - - - ②

Where, C = 1.2(resistance coefficient at rough seas),

F_2 = 1.0 (coefficient from table 2 according to bow shape)

A2 : 184.5 (cross sectional area of submerged part, m^2)

V = approximately 1.5 knots (towing speed), 7 knots if towing speed is unknown.

$Ra = 1.95 \times 10^{-5} \times Cs \times C_H \times A_3 \times (Vw + V)^2 = 72.16$ tons - - - - - -③

Where, Cs = 1.5 (from factor of hull facing wind)

C_H = approximately 1.3 (height of centroid of windage area above water)

A_3 = 1,285 (total cross sectional area of windage area above water if the crane angle is 40°)

Windage area is 2,000 (the whole surface) x sin40° = 2000 x 0.6428 =1,285 m^2

Vw = 36.93 (=approximately 19 m/s. velocity of wind in knots, value of coastal area as calculated in accordance with the table of the standard as per sailing area)

V = approximately 1.5 knots (7 knots if towing speed is unknown)

Rt = Rf + Rw + Ra = 1.42 + 6.97 + 72.16 = 80.55

And, Rs = 5.5 tons (the value for Significant Wave Height 3 in Schedule 5 of the Standard) - - - - - ④

Thus, R (the total resistance of Samsung No.1)= Rt + Rs = 80.55 + 5.5 = 86.05 tons - -- - ⑤

Therefore, under the weather condition at the time of the accident, the bollard pull of the tugboats, Samsung T-5 and Samho T-3, and the total resistance imposed on Samsung No.1 is

Bollard Pull (94.7 tons) > Total resistance (86.05 tons)

That is, the total resistance was about 90.8% of the bollard pull, which says that there was spare bollard pull of 9.2% of the total.

However, taking into account that ①as the bollard pull test of Samsung T-5 was conducted in Dec. 1995, 12 years before the accident, the actual bollard pull of the two tugboats at the time of the accident shall be taken as quite lower than the 94.7 tons as mentioned in the shipbuilder's report in view of the main engines' many years of usage. ②The total resistance shall include Roll, Heave, and Pitch, the components of movement on waves intrinsic to Samsung No.1 and dynamic loads which is inertial force being active when surge, sway, and yaw change at a moment on still water. ③ and, strictly speaking, the resistance imposed on the tugboats although trifle compared to that imposed on Samsung No.1, shall be included in the total resistance. It is

proper to take the actual bollard pull and the actual total resistance at the moment as

Bollard pull ≒ Total resistance

On the other hand, the track of the towing fleet tells us that the towing fleet was losing its towing ability from 02:00 and lost virtually all of its towing ability by 04:00 when the Master decided to take shelter, which means the total resistance became equivalent or larger than the towing ability. The relationship between the towing ability and the total resistance around such time was:

Actual bollard pull = total bollard pull (94.7 tons) – depreciation due to main engine's many years of usage

Actual total resistance = total resistance (86.05 tons) + resistance to the tugboats + dynamic loads

That the towing fleet could not move or moved at a very low speed of 1.5 knots as the bollard pull was almost same as or equivalent to the total resistance, and that the tugboats kept towed to the barge as the total resistance exceeded the bollard pull when the sea got rougher, making the track of the towing fleet serpentine and pushing the towing fleet from its course.

This analysis exactly corresponds to the actual track of zigzags of the towing fleet up until the collision from 00:30. (*See* [Figure.18], [Figure.19])

That the towing ability was not enough to cope with the weather condition on the day of the accident, was a direct cause.
(Direct Cause 1 of Collision: Lack of towing ability of the towing fleet)

4.1.2.2. Towing survey

4.1.2.2.1. Purpose and Meaning of the towing survey

In order to prepare against risks of towing voyage of Samsung No.1, Samsung Heavy Industries asked, at its own expense, a towing survey to BMT, Hong Kong, for the purpose of subscribing a Hull insurance for the ship, which was actually conducted by Hyopsung Survey in Korea.

Although the marine insurance contract is a private contract, the towing survey is a safety inspection confirming whether the towing fleet is able to perform successfully the towing voyage before the subscription of the insurance, presents navigational recommendations for safe towing voyage on the survey result, and is approved on condition that the Master should comply with such recommendations. Thus the report of the towing survey and usage of the towing fleet's facilities and equipment as mentioned in the towing approval check list, weather condition and the time to take shelter shall become a practical safety guideline for the Master who conducts the towing voyage.

The result of the towing survey, on the one hand, plays a role of Insurance Survey confirming the safety of the towing fleet for the insurer, and of a safe sailing guideline for the Master of tugboat. On the other hand, the towing surveyor shall confirm the composition and strength of towing equipment such as towing wire, trigon, stretcher, pennant wire etc. as well as seaworthiness with respect to buoyancy and stability of the towed object.

The survey shall be based on scientific ground and applicable regulations in presenting navigational recommendations so that seafarers may overcome any sea peril. And the Master who conducts towing voyage shall comply with such conditions for approval of survey and navigational recommendation to make ensure safe voyage on the sea where unexpected risks and dangers exist at all times.

However, the towing surveyor and the Master of the tugboat in this case carelessly ignored their obligations as follows:

4.1.2.2.2. Method of towing survey (safety check)

4.1.2.2.2.1. Composition of the towing wire ([Figure 12] [Figure 13])

According to the towing approval check list of the towing survey, Samsung T-5 used a steel wire of 47.5 mm in diameter, 600 m in length. On the other hand, Samho T-3 used a steel wire of 50 mm in diameter, 500 m in length, with a stretcher for shock absorption of P.P rope of 100 mm in diagram and 200 m in length.

If the stretcher of P.P rope with better elasticity, is used with a steel wire, it protects the towing wire from snapping, as it stretches the time during which a strong and sudden tension works. When the main wire, a steel wire, is used connected to a stretcher, it should be used on Samsung T-5, which has a more powerful bollard pull, (there is a big difference in power between the two tugboats' main engines, but their actual bollard pull is not greatly different. Nonetheless, during the towing survey, an inaccurate bollard pull was used as if Samsung T-5 were much better) or the length of Samsung T-5's towing wire should be longer than that of Samho T-3, so that the tension may spread to prevent it from snapping.

On the contrary, they used a steel wire, which is less shock absorptive, for the towing wire of Samsung T-5, which had more or less greater bollard pull and was that much shorter than the other. This does not tell us that there was any reasonable standard followed by them in determining the towing wires. Moreover, the Master of Samsung T-5 ignored the guideline for the composition and length of the towing wire as specified in the towing survey report, since he thought the length of the towing wire was too long to control.

The navigational recommendation allowed the Master to adjust the length of the

towing wire, but the composition of the towing wire mentioned in the towing survey was unreasonable with which the Master did not comply. Thus, the composition of the towing wire, one significant factor that affects the success of a towing voyage was completely ignored.

Although the side where the smit bracket was decided to be set (towing side connecting the towing wire) could be interpreted as wrongfully described on the towing approval check list, because Samsung No.1 was towed inversely fore side back, the side was confirmed to be mentioned correctly by the towing surveyor during the ruling. In other words, the towing formation of the tugboat in the survey corresponds with the real, but the composition of the towing wire was unreasonable and did not comply with the actual sailing.

Although the towing survey is merely a part of the contract between the concerned parties subscribed to the insurance but is not a legal requirement, and the composition of the towing wire mentioned in the towing approval check list, even if unreasonable, was not complied with by the towing fleet, the conditions presented or prescribed by the towing survey practically plays a role as a safety guideline for the Master. The towing survey is a confirmation whether a towing voyage may be conducted safely. Following such conditions improperly makes it lose the opportunity to remove risks in the towing voyage in advance, which is akin to officially leaving it at bay and promoting circumstances that exposes the fleet to sea perils.

4.1.2.2.2.2. The total resistance of Samsung No.1

During towing operation in bad weather, the tension of dynamic loads to the towing wire fluctuates very much according to the ship's movement on irregular seaway, and the towing wire snaps when the instant tension is not properly absorbed. To prevent this, that which is necessary to ensure the safety of towing operation, including the length and strength of the towing wire, etc. are specified in detail in the "Standard for Structure and Equipment, etc. of Barge," "the Regulations on Towing Survey of Barge" (KR, Korean Register of Shipping), "MSC/Circ.884 Guidelines for Safe Ocean

Towing" of IMO, etc.

The total resistance when dynamic loads are imposed on Samsung No.1, as calculated in accordance with "the Standard for Structure and Equipment, etc. of Barge" as above, exceeded 86.05 tons.

However, the resistance as calculated by Hyopsung Survey, when conducting the towing survey, is quite different from the above calculation. That is:

$Pf = 0.01 \times S \times V^2$

Pf : frictional resistance (pound)

S : Wetted surface area

V : Velocity (knots)

$Pd = 2.86 \times Ks \times Ad \times V^2$

Pd : wave resistance (pound)

Ks : 0.75 - 1.0 (from factor of submerged part)

Ad : projected area of submerged part (ft2)

$W = Z \times A \times Vw^2$

W : wind force

Z : 0.003 (from factor of windage area)

A : Projected windage area

Vw : Velocity of wind (knots)

Although this formula is different from the formula specified in Korean rules as specified above, the items that calculate 3 resistances as frictional resistance, wave making resistance and air resistance are the same. However, Hyopsung Survey omitted air resistance (wind pressure) in the calculation, which influences the most during bad weather. It also did not consider the influence of waves at all.

[Table3-1] shows the calculation carried out by Hyopsung Survey in accordance with S.A. (Salvage Association of UK) standards. Previously, the total resistance imposed on by the rough seas at 1.5 knots of towing speed was calculated as being 86.05 tons (excluding dynamic loads due to ship movement). However, the total resistance in the following calculation was 14 tons at the most even when the towing speed

was 3 knots, which is far from reality.

It is improper to judge the safety of a towing voyage by means of such values.

[Table3-1] The total resistance of Samsung No.1 as calculated by Hyopsung Survey in accordance with S.A. standard.

[Spec. of Samsung No.1]
L: 348 ft
B: 148 ft
185 tons
D: 23 ft

d: 7 ft
S: 55223 sqft
Ad: 969 sqft
Cb: 1
Ks: 1

[Resistance formula}
Pd = 2.86 x Ks x Ad x V x V
Ks = 0.7-1.0

Ad = B x d
(Projected Underwater Area)
Pf = 0.01 x S x V x V
S = 1.7 x L x d + L x B x Cb
1 ton = 2205 pounds

[Other factors]
Length of tugboat: 36 m
Towing Rope Breaking Load:

Tug Bollard Pull: 50

Speed in knot	3	4	5	6	7	8
Pd (pound)	24936	44330	69266	99743	135761	177320
Pf (pound)	4970	8836	13806	19880	27059	35343
Rt (pound)	29906	53166	83072	119623	162820	212663
Rt (ton) (total resistance)	**14**	**24**	**38**	**54**	**74**	**96**

Minimum tow line	KMU/ KR	Coastal	1.5 x (length x L2)	213 m
		Ocean	3.5 x (length + L2)	497 m
	SA	**L > 1800 x BP/BL**		**486 m**

Although the towing wire's composition and calculation of the total resistance imposed on the towed object are crucial factors in determining the safety of a towing voyage, improper towing survey neglecting as such was not unrelated to the snapping of the towing wire, which was a direct cause of the collision in this case. (Cause of Collision 2. Improper towing survey as part of direct causes)

4.1.2.2.3. Nonconformity to voyage recommendations ([Table3])

As the towing survey report stated voyage recommendations for safe towing, the

Master of the main tugboat should have complied with them, but failed in complying with the following:

4.1.2.2.3.1. Communication in case of deviation for taking shelter

Deviation from the intended course due to any reason during sailing shall be notified to the ship owner or the towing surveyor. However, such notice was not made at all in this case, such that the ship owner or the towing surveyor could not notify the concerned authorities or VTS Center, which in turn could not notify the ships nearby. Thus, the towing fleet could not get any external assistance.

4.1.2.2.3.2. Failure to give prewarning to ships nearby and to notify concerned authorities

Moreover, when the towing fleet lost its towing ability completely and got carried away, it should have informed concerned authorities and others on shore and nearby ships of its situation by all means, so that those informed could have prepared to respond to the situation, which is a basic obligation under ordinary practice of seamen (seamanship) as mentioned in the IMO guideline. However, the towing fleet did not fulfill such obligation, and was negligent in notifying about its situation to others, failing to reply to a call from the VTS Center of Daesan Port 1.5 hour before the accident.

Moreover, the towing fleet's failure to notify to the concerned authorities and others on shore and nearby ships by all means about its emergency situation of having lost towing ability completely and being carried away, which would have allowed them to take safety measures early. It is therefore an indirect cause of the collision. (Indirect Cause 3 of Collision: Failure to notify to others about its emergency situation)

4.1.2.2.3.3. Obtaining weather information and the timing to take shelter

The weather forecast which the Master of Samsung T-5 obtained when he departed from Incheon Port was that a gale warning would be issued for the distant mid-Yellow Sea 20 miles off the coast at 03:00 on Dec. 7, 12 hours after departure.

The Master nonetheless departed from the port, because he thought that such weather conditions would not affect his fleet since the fleet would sail at only 5 miles off the coast.

However, the towing ability started to deteriorate, when the rough seas from the open sea beat the towing fleet when it passed by Uldo Island, at the southern end of Deokjeok archipelago. This is when the Master went to bed after his navigational watch. The Chief Officer, who took over navigational watch, kept sailing without calling the Master as he did not take the situation seriously.

He should have called the Master, so that the fleet could take shelter when the wind exceeded Beaufort Scale 6, in accordance with the voyage recommendations of the towing survey. The officer on duty notified the situation to the Master when the towing ability got worse, thereby failing to allow the Master to have the fleet take shelter early in time. This shows the Master's negligence in supervising the mate on navigational watch.

Missing the timing to take shelter is a direct cause. (Direct cause 4 of collision)

4.1.2.3. Strength of towing wire and reason for snapping

4.1.2.3.1. Strength of Samsung T-5's towing wire

Samsung T-5's towing wire, which snapped right before the accident, was manufactured and shipped in 1995. It had been kept in the ship after its use as a luffing wire for the crane of Samsung No.1, and began to be used again as a towing wire in June 2007, about 5 months prior to the accident. The breaking loads in the manufacturer's test result, test results of the National Institute of Science Investigation (NISI) after the accident, and the strength as required by related regulations, are stated in [Table3-2].

[Table3-2] Performance of the broken towing wire used by Samsung T-5

Breaking loads in Manufacturer's test result: **217 tons,**
Safe work loads:**99 tons**
Breaking loads tested by NISI after accident: **182.2 tons** (some 16% depreciation of a new product).
Required minimum breaking loads of the towing wire used by Samsung T-5 under the Standard for Construction and Equipment, etc. of Barge : **136.9 tons**

As a result of the test conducted by NISI on 8 sample pieces obtained from the towing wire that snapped, the average breaking loads was revealed as being approximately 182.2 tons, which is some 16 percent weaker than at the beginning. Minimum breaking loads(MBL) of the towing wire used by Samsung T-5 under "the Standard for Construction and Equipment, etc. of Barge," calculated by applying 48.3 tons of the bollard pull, is as follows:

As the bollard pull(BP) is 40 =< BP >= 90,

MBL = (3.8 - BP/50) x BP = (3.8 - 48.3/50) x 48.3 = 136.9 tons

Which is much less than the test result (182.2 tons)of NISI, so no problem is deemed to have existed in the towing wire's strength that snapped.

As the strength of the towing wire that snapped, exceeded the minimum breaking load (MBL) under applicable regulations, it did not cause the snapping. (Cause of Collision No. 5: Strength of the towing wire that snapped, as unrelated to the causes)

4.1.2.3.2. Reasons the towing wire snapped

There may be several possible reasons why Samsung T-5's towing wire snapped, but in any case it is obvious that the towing wire snapped, because it failed to withhold

the tension. Reasons the towing wire snapped include ① a case in which the towing wire failed to instantly withhold dynamic loads while the direction of the towing wire was normal; ② a case in which the excessive bending loads bent the towing wire by a wide angle at the stern choke or in which the cleat of Samsung T-5's guide bar exceeded the bending breaking strength, or ③ a case in which the towing wire is damaged by an object of Samho T-3.

Of the three cases, the first case is being analyzed:

4.1.2.3.2.1. Exceeding breaking load due to dynamic load

The breaking load of the 8 sample pieces of the snapped towing wire, tested by NISI, was 182.2 tons. And the total resistance of the static load under the weather of the day of accident was 86.05 tons. Therefore, the dynamic load gap between the two, in this case, should be greater than 96.15 tons, for the towing wire to snap.

The dynamic load is the only force that can impose not less than 96 tons of force on the towing wire, which connects the tugboat with the barge towed moving on waves.

On the other hand, the total resistance imposed on the towing wire usually is composed of frictional resistance, wave-making resistance and air resistance and additional resistance due to waves as mentioned above. Among them, air resistance which is wind pressure is the heaviest (72 tons), and the rest do not exceed 10 tons. However, even air resistance in nature may not work heavily against the towing wire at a moment.

If so, another load that can potentially be imposed on Samsung T-5's towing wire is the dynamic load or the inertial force from the movement of Samsung No.1 and/or Samsung T-5. Of these, Samsung No.1's displacement is as heavy as 16,000 tons.

As above, there may exist no other forces which exceed 96 tons of the towing wire's

dynamic load except for the force arising out of the movement of Samsung T-5 and Samsung No.1 on the waves, because it is not difficult to expect both ships to move separately away from each other and generate the maximum dynamic load. The load can arise when the pitching cycles run the opposite direction

On the other hand, while sailing on the rough seas, irregular movement of a tugboat and the barge increases the towing wire's dynamic tension amplification. If dynamic tension amplification is excessive, the minus dynamic tension (the force to the towing wire's contractile direction) may exceed the plus static tension of the towing wire, therefore the total tension could be 0 or minus.

That the towing wire slackens and then "snaps," when heavy plus tension is imposed on the towing wire very quickly causes the wire to break or shorten the wire's life. In this case, the towing wire seems to have broken from such snapping.

In calculating the dynamic tension imposed on the towing wire through slack-and-snapping, simple arithmetics is used here as follows.

In the formula, we put dynamic loads as DL. As DL is the total dynamic loads of Samsung No.1 and Samsung T-5, we put dynamic loads of each boat as DLs1 and DLT5. And as dynamic loads of Samsung No.1 was the first loads imposed on the towing wire through smit bracket, we put such loads as DLs1:

DLs1 = m x ap = 4,612 tons.

m: mass of Samsung No.1

ap: lineal acceleration to the direction of the towing wire by smit bracket movement

The horizontal component is 239.8 tons.

By the same formula, the dynamic loads, DLT5, imposed on the towing winch drum by pitching Samsung T-5

DLT5 = m x ap= 207.2 tons

m: mass of Samsung No. 1

ap: lineal acceleration to the direction of the towing wire by winch drum's movement of Samsung No.1

The horizontal component is 14.3 tons.

Therefore, the total dynamic loads is,

DL =DLs1 + DLT5 = 239.8 + 14.3 = 254.1 tons

As calculated above,

Threshold dynamic loads in the accident = 182.2 (maximum breaking load tested by NISI) - 86.05 (total resistance) = 96.15 tons, which well exceeded the dynamic loads by 254.1 tons.

If Samsung No.1 and Samsung T-5 pitch only 3° and 3.9° individually when the pitching cycles run the opposite direction, 254 tons of instant dynamic loads is added to the towing wire.

The dynamic loads alone exceed minimum breaking loads (136.9 tons), let alone the static loads. In case such value is transferred to the towing wire, just as it was, the towing wire may be broken.

Dynamic loads, even if so strong, are spread out while the curved catenary portion straightens out as the center of the towing wire hangs down deep in the water. Therefore, a strong dynamic load by itself does not necessarily lead to the breaking of a towing wire.

In sum, while Samsung T-5 accelerated rapidly at full speed to avoid collision with

Samsung No.1 so that the catenary portion of the towing wire was straightened, dynamic loads, not being spread out - and worked all at once to break the towing wire.

4.1.2.3.2.2. Analysis of case ②

Case ② is less feasible or possible than case ①.

If the towing wire broke due to strong friction imposed on choke or guide bar, This does not coincide with the fact that the broken part was 60 m away from Samsung T-5's stern. But also because the two tugboats were not so far crossing, such a wide angle could not have been made even if the towing wire were hooked with a choke or guide bar.

The frictional mark found on the inner part of the choke or guide bars is also often found on fair leader, bitt, or bollard on the deck.

Notwithstanding, even though the towing wire broke because of strong bending tension while passing the choke or guide bar, the fundamental reason for such strong tension lay in dynamic loads.

4.1.2.3.2.3. Analysis of case ③

With regard to case ③, there is the possibility that the towing wire of Samsung T-5 got damaged or broke from friction when it was held by shell plating of the hull around port stern of Samho T-3. But, the part is shell plating with a curved surface, such that the towing wire could not be damaged, and as the propeller is located in a duct so the possibility of damage is also dim.

The reason the towing wire broke lies in the dynamic loads imposed on the hull on waves which exceeded breaking strength worked onto the towing wire in a short moment, but not because the towing wire did not have enough strength. In addition, that the fleet failed to comply with the composition (combination of materials etc. but not the length) of the towing wire mentioned in the towing approval check list also caused the wire to break.
(Cause of Collision 6. Reason of the broken towing wire as part of direct causes.)

Thus, the towing wire of Samsung T-5 broke from dynamic loads which exceeded maximum breaking loads, and not by use of nonconforming towing wire having less strength than prescribed was used. However, if the catenary portion of the towing wire or the towing wire itself were long enough to spread out the time during which the loads work, the towing wire would not have broken.

In this aspect, it may be said that the fact that they did not combine the towing wire with poly-prophylene stretcher which works as a spring to absorb impact or that they did not unwind the long towing wire enough to delay the time during which tension works as mentioned in the towing approval check list (*See* [Figure.12], [Figure.13]) caused the breaking of the towing wire to break.

However, too long a towing wire may hamper the steering of the boat. Thus they should have followed the composition as mentioned in the towing approval check list, and then used more tugboats to strengthen the bollard pull while shortening the length of the towing wire to make steering easier.

4.1.2.3.3. How the breaking of the towing wire is related to the collision

At 06:52 of December 7, Samsung No.1 was located at a distance of approximately 0.4 mile from Hebei Spirit right after having passed by the Distance of Closest Point of Approach ("DCPA" approximately 0.3 mile). Thus, if the towing wire had not broken, they would not have collided.

If they proceeded as they did, the risk of collision would have cleared. But the towing wire broke, and Samsung No.1 drifted in the heavy seas, only to collide.

The breaking of the towing wire is a direct cause of the collision. (Direct cause 7 of collision)

4.1.2.4. Anchoring in emergency

Immediately before the collision, Samsung No.1 anchored in emergency, but it could not prevent the collision. In this regard, we have to find out whether the reason why they did not anchor in emergency even earlier was because of small holding power, or whether anchoring in emergency could have prevented the collision, and if anchoring in emergency was possible in such a bad weather.

4.1.2.4.1. Analysis of Samsung No.1's holding power and external force

How much holding power Samsung No.1 could obtain if it cast 13 out of 15 shackles of the anchor chain to prevent the drift, is calculated here.

Wa (Weight of anchor) = 19.7 tons

Wa1 (Weight of anchor underwater) = Weight of anchor - (specific gravity of seawater x Weight of anchor/ specific gravity of anchor)

= 19.7 - (1.025 x 19.7/7.8) = 17.1 tons

Wc (Weight of 1 m of the anchor chain)

= 0.206 tons (Total weight of anchor cable = 84.975 tons)

Wc1 (Weight of 1 m of the anchor chain underwater)

= 0.206 - (1.025 x 0.206/7.8) = 0.179 tons

Length of 1 shackle of anchor cable = 27.5 m

h =64 m(Depth) + 2 m (Sea level of Hawser Pipe) = 66 m

H : horizontal component of tension put on the anchor chain

To put the length of the catenary portion of the anchor chain under the weather of the day as Lc,

$Lc = [h\{h+2(H/Wc1)\}]^{1/2} = [66\{66+2(H/0.179)\}]^{1/2}$

The total resistance of Samsung No.1, as calculated in accordance with the "Standard for Construction and Equipment, etc. of Barge," is the sum of Rf (frictional resistance), Rw (wave-making resistance) and Ra (air resistance) and additional resistance due to waves. But external forces H when at anchor is the sum of wind pressure (Ra. air resistance), current resistance (Rc), drift force (Rd. Drifting)

$H = Ra + Rc + Rd.$

Under the worst condition, we suppose that Samsung No.1 faced the windward side after dropping the anchor, and that the tidal current was southwesterly about 2 knots under the wind pressure at the moment.

The exact value of the holding power of Samsung No.1 is important. But the purpose here is to confirm whether such holding power could withhold external forces.

Applying the same formula as the one we used when calculating the total resistance of Samsung No.1 as above,

$Ra = 1.95 \times 10\text{-}5 \times Cs \times CH \times A3 \times (Vw + V)^2 = 66.6$ tons - - - - - -③

Where, Cs = 1.5 (form factor of hull facing the wind)

CH = about 1.3 (height of centroid of windage area above water)

A3 = 1,285 total cross sectional area of windage area above water:if the crane angle is 40°, actual wind projected area is 2,000 (whole surface) x sin40°

= 2000 x 0.6428 =1,285m^2

Vw = 36.93 knots (=approximately 19 m/s)

V = 0 knot (ship's speed)

As presupposed above, to find out if the holding power could withhold the strongest external forces, the maximum current resistance (Rc) in due horizon is calculated and used, as with the horizontal component of the anchor chain. This value is also used to determine the effect of anchoring Samsung No.1. Since the towing fleet argued that anchorage was not effective due to strong external forces, the current resistance in due horizon is deemed as affecting the anchor chain as it is to find out the strongest possible external forces.

$Rc = 1/2 \times \rho w \times Cw \times A \times V^2$

$=1/2 \times 0.1046 \times 1.2 \times 353.8 \times 1 = 22.2$ tons

ρw : sea water density (0.1046 tons $\cdot sec^2 \cdot m^{-4}$) Cw : current force coefficient (approximately 1.2)

A : submerged area (length x average draft = 105.6 x 3.35 = 353.8m^2)

V : current speed (approximately 1m/sec)

[Table 3-3] Drift force coefficient (R) of irregular seaway

On irregular seaway, the drift force coefficient R is marked as the wave number (k) and the function of draft (d), and the wave number is the function of the wave frequency (w), and the wave frequency is in functional relationship with the frequency (Tz). The calculation to find R was made based on approximately 31 knots (average of approximately 16.5 of 15-18m/s) of wind speed at the time of the accident.

As a way of expressing the status of the specific irregular seaway, the standard wave spectrum was used, and this was to prepare the spectral density formula of the ITTC (International Towing Tank Conference), and this area of the spectrum is made in the variance, m_o, and the second and fourth moment of the spectrum are indicated as the marine accident, m_4, and it is expressed with the sea condition at the time as follows.

Wave height ($H1_{/3}$) = 4.0 x $m_{o\ 1/2}$ = approximately 18.5 ft (= approximately 5.6 m)
Average wave height ($H_{average}$) = 2.5 x $m_{o\ 1/2}$= approximately 11.67 ft. (= approximately 3.6 m)
The average wave height found here was around 4m of wave at the time of the accident, the same as the statements made by witnesses. It was almost consistent to the wave height and the wind force grade of [Table 3-4] on the Beaufort Scale.

$No = 1/(2 \times \pi) \times (m\ 2\ /\ m_o)^{1/2} = 0.1132$ /sec, $Tz = 1/No = 8.83$ seconds

No: Zero up-crossings per second

Tz: No of reverse water (Average zero-crossing period).

m_o = 21.564 ft 2 (Area integrated by preparing the wave spectrum)

m_2 = 10.91 ft 2/sec 2 (Second momentum of wave spectrum)

m_4 = 9.52 ft 2/sec 4 (forth momentum of wave spectrum)

Therefore,

w (wave frequency) = 2 π /Tz = 0.711

k (wave number) = w2/g = 0.052

k x d = 0.052 x 3.35 = 0.1742 (d: average draft)

With this value, the drift force coefficient R is found in the drift force coefficient curve, which is approximately 0.34

[Table 3-4] Classification of the Beaufort Scale (Part filled with the shaded color is the wind power at the time of the collision)

Wind force grade	Wind velocity		Name	Average wave (m)
	Knot	m/sec		
3	7 - 10	3.4 - 5.4	Gentle Breeze	0.6
4	11 - 15	5.5 - 7.9	Moderate Breeze	1
5	16 - 21	8.0 - 10.7	Fresh Breeze	2
6	22 - 27	10.8 - 13.8	Strong Breeze	3
7	28 - 33	13.9 - 17.1	Moderate Gale	4

The drift force is calculated as the bow is facing the tide when anchoring.

$Rd = 1/2 \times \rho w \times g \times \zeta^2 a \times R^2 \times A \times \sin^2 \alpha = 10.7$

However, ρw: The density of sea water = 0.1046 ton x sec2 · m^{-4}

g: Gravity = 9.8 m/sec2

ζa: Wave amplitude (Hw (wave height) x 1/2 = 2)

R: Drift force coefficient = 0.34 ([Table 3-3] refer to calculation process)

A: Ship Width (45m)

α: Angle of wave

Therefore, the sum of external force (horizontal direction), H= Ra + Rc + Rd = 66.6 + 22.2 + 10.7 = 99.5 tons

The calculated external force (99.5 tons) is greater that the value when the ship is sailing at 1.5 knots (86.05 tons) because in this calculation the maximum current force is applied.

Using these values, the length of anchor catenary will be;

$Lc = [h\{h+2(H/Wc\ 1)\}]^{1/2} = [66\{66+2(99.5/0.179)\}]^{1/2}$

$= \{66(66 + 2 \times 555.9)\}^{1/2} = 77{,}735^{1/2}$ = approximately 278 m (approximately 10.1 shackles)

Therefore, when Samsung No. 1 used 13 shackles out of 15 shackles, about 10.1 (appx. 278m) shackles could have formed the catenary and the remaining 2.9 shackles (appx. 79.5m) would have been used for holding power.

When Pa and Pc is holding power of anchor and anchor chain respectively, the total holding power P will be;

$P = Pa + Pc = Wa \times \lambda a + Wc \times \lambda c \times Lp$

$= 17.1 \times 3.5 + 0.179 \times 1 \times 79.5 = 59.9 + 14.2 = 74.1$ tons

For that,

Wa = anchor weight under water,

λa = wave coefficient of anchor,

Wc = weight of 1m of anchor chain under water,

λc = Wave coefficient of anchor chain,

Lp: length of anchor chain forming the holding power

In summary,

Sum of the external force (wind pressure, drift force, current force) 99.5 tons > holding power of 74.1 tons when slackening 13 shackles of anchor chain

This shows that when 2.9 shackles were used for holding power, it would lack 25.4 tons of holding power. However, if two towing boats were used with 86.06 tons of bollard pull, the additional 60.65 tons of bollard pull (86.05 - 25.4 = 60.65) could have been sufficient for anchoring. Even if there might be variations in this calculation, it clearly indicates that they were able to anchor without any problem.

In conclusion, the Samsung No1's allegation for not trying anchoring in emergency, because there was not enough holding power, can not be accepted. This calculation suggests that if Samsung No.1 had tried early to anchor in emergency, it was possible to avoid the collision.

4.1.2.4.2. Analysis of anchoring possibility

Master of Samsung T-5 had the towing wire broken at around 06:52 of the accident day and requested Fleet Manager of Samsung No. 1 to take emergency action, and bosun with the instruction of Fleet Manager went out to the stern deck along with two crew men to prepare to anchor and actually anchored at 07:00, and the collision happened at 07:06. Up to 5.5 shackles of anchor chain were slackened.

As such, the time that the Fleet Manager of Samsung No. 1, who was requested to take emergency action from Master of Samsung T-5 instructed the bosun to prepare anchoring at 06:54, and it took only 6 minutes after the instruction until bosun anchored at 07:00.

At the time, barge Samsung No. 1 had difficulties in anchoring due to bad weather at the moment. It was an emergency situation with the towing wire broken, but it was able to anchor in only 6 minutes. Thereafter, it released 5.5 shackles by 07:06, and then had 12 out of 15 shackles released. Therefore, if the Master of Samsung T-5 intended to anchor before the towing wire broke, early anchoring would have been possible without much difficulty.

Samsung No. 1 did not anchor early in emergency before the towing wire broke, because the barge did not recognize the risk of its drifting toward the large oil tanker. Instead, the Master focused its attention on commanding the towing fleet that he lost its towing ability.

4.1.2.4.3. Analysis of risk of taking shelter windward

In addition, if the towing fleet had moved to windward of Hebei Spirit instead of moving leeway of Hebei Spirit, it would have been able to maintain a safe distance from other anchored vessels. The towing fleet's decision to move to windward of Hebei Spirit and not anchor in emergency led to the collision.

Samsung No.1's moving to windward of Hebei Spirit and its failure to anchor at an early stage, are direct causes of the said collision. (Direct cause 8 of collision)

4.1.2.5. Lookout

Master of tugboat Samsung T-5 was determined to return in order to take shelter because of a serious decline in its bollard pull at around 04:00 of December 7. It began to change course to take shelter at around 04:44. From then on, the track of the towing fleet began to move in different directions from the intent of the ship operator, to the extent that it was easy to see with bare eyes the three large ships, including Hebei Spirit within two miles South of the area.

While the towing fleet was drifting around, unable to control, and creating a risky situation, Samsung T-5 and Samho T-3 did not inform the risk to nearby ships. At around 05:23, it did not respond to the VHF call from the VTS Center of Daesan Port that it did not properly keep lookout. It would be understandable to neglect its obligations by focusing only on towing Samsung No. 1 under the difficult situation, but it would not exempt them from the responsibility of the collision as set forth under COLREG.

Therefore, the tugboats' actions would be deemed as lookout negligence under COLREG.

Lookout negligence by the towing fleet was a direct cause of the collision. (Direct cause 9 of collision)

4.1.3. Analysis of Hebei Spirit's causal factors that contributed to the collision

In order to analyze and determine the direct and indirect factors of Hebei Spirit that caused the collision, it would be necessary to take a look at the appropriateness of its

anchorage selection and crew's anchor watch, the readiness of its main engine while anchored, and the appropriateness of measures taken to avoid the collision.

4.1.3.1. Appropriateness of anchorage selection

At the time of the accident, Hebei Spirit was anchored at 255° from Sindotaseo's lighthouse in Wonbuk-myeon, Taean-gun, and at approximately 4.8 miles, or at 36°52'29"N-126°03'14.5"E. The weather was not bad at the time, with the exception of a strong tide and slightly deeper water. This was a favorable condition for a very large crude oil tanker with a draft of approximately 20 meters and 323.8m in length, to anchor.

However, this area was approximately 7 miles Northeast of the TSS in Gadaeam-Heuk-do, where the northern access of the TSS (Traffic Separation Scheme) was located. In addition, it was where Incheon Port, Daesan Port, and Pyeongtaek Port intersect, creating the risk of possible collisions with other ships passing through the coastal area. Plus, this was an open sea without any shelter and the anchorage location of 64 meters of depth in the water, which could not expect the holding power with its seabed in sand and the strongest tidal flow of 3 knots or higher, with a high risk of anchors dragging under bad weather conditions. In the event of anchoring in this type of place, a ship would need to maintain a navigational watch system in order to respond to a collision risk or drag the anchor.

The Hebei Spirit was anchored with clearly a high risk of colliding or dragging of its anchor. In this case, the accident occurred, because the towing fleet had serious impairments in its maneuvering abilities resulting in the tugs drifting into Hebei Spirit's side, and Hebei Spirit failed to maintain the readiness of its main engine. If the ship had not failed to perform its on-duty watch when anchored, and had maintained its main engine ready to use, the collision could have been avoided. Therefore, selecting a place with a higher probability of a collision occurring or simply dragging anchor, cannot be considered enough of a direct cause of an accident.

4.1.3.2. Anchor watch

The ship should continuously maintain navigational watch when anchored, when necessary. While anchored, the duty officer on navigational watch has to maintain a proper lookout and observe meteorological and tidal conditions and the sea state; (STCW Code PART A Chapter 8)

In addition, the equipment and personnel have to be maintained to sufficiently respond to any situation while anchored. Anchor watch should be followed more cautiously in such a situation, as there would be concern in terms of safety and security of the ship. The Master has to inform the Chief Engineer of readiness to use the main engine, and the steering gear or deck equipment.

An appropriate lookout would need to be maintained while anchored. Careful watch for any approaching ships is also required. If there is any possibility of a risk of collision and if other ships's intent is suspicious, immediate contact between the ships by means of light signals or VHF and others is required. (FLEET OPERATING MANUAL by ISM regulations)

In summary of the situation in this case, given the situation of its anchorage and/or bad weather being forecasted, the Master of the Hebei Spirit should have continuously maintained navigational watch in order to sufficiently respond to any situation while anchored. However, he changed navigational watch into anchor watch, as such providing the reason for the Chief Officer to neglect his on-duty responsibilities.

If the Chief Officer of Hebei Spirit had duly performed his anchor watch appropriately, when the towing fleet began to drift toward Hebei Spirit at approximately only 3 mile, creating the risk of a collision at around 04:00 when weather conditions got worse, he would have been able to recognize the situation with enough time to react.

In addition, if he had properly observed with the ARPA radar and examined the lights turned on the tugboat for navigation, the appearance under the light, the change of direction as reflected under the light, the Chief Officer would have realized that from 04:40, when the tugboat tried to take shelter, it changed the towing direction from South to North, while the barge progressed to the East. He would have also realized how from 05:30, the tugboat had finally given up on taking shelter and changed the towing direction from North to West, but how its barge drifted South and approached Hebei Spirit again.

If the Chief Officer had properly undertaken his on-duty responsibilities, he would have realized how the distance between the towing fleet and Hebei Spirit had narrowed to about 1.5 mile and how at around 05:30 or about 1 hour and 37 minutes before the collision, the towing fleet's navigation was abnormal, bearing a risk of collision with Hebei Spirit.

In the meantime, if the Chief Officer had immediately reported the situation to the Master upon realizing it, the Master would have had enough time to heave up the anchor chain and use the main engine to avoid the collision, as the approaching speed of the towing fleet was very slow at only about 1.5 knots, even though they were approaching at a close distance.

However, Hebei Spirit did not properly carry out anchor watch at night and thus failed to recognize any risk of serious collision until the towing fleet - measuring a total of 730 meters with very bright working lights clearly distinguishable at night- navigated in a zigzag motion, drifted toward approximately 90° of the intended course, and approached Hebei Spirit by as close as 0.7 mile.

While the Hebei Spirit was anchored, they did not maintain proper anchor watch, nor did they deploy a qualified officer in charge of watch keeping, providing substantial direct causes of the collision.
(Cause 10 of the collision: Inappropriateness of on-duty system at anchor and default of on-duty navigational watch by Hebei Spirit. Substantial direct cause in this case.)

4.1.3.3. Readiness of the main engine while anchored

When anchored where it is not sheltered, the Chief Engineer should consult with the Master if they need to maintain the same on-duty system on the engine as during navigation. When anchored at an unsheltered outer port anchorage, the on-duty officer responsible for the engine should carry out regular inspections of all machines in operation and in stand by. Also, the main engine and auxiliary machines should be kept prepared according to commands from the bridge. (STCW Part A, Chapter VIII).

Unless it is an inevitable situation, maintenance work on the main engine that can obstruct it from operating, should not be carried out while anchored (according to the Fleet Operating Manual).

As described earlier, Hebei Spirit's anchorage held a high risk of collision with passing ships and no shelter. In addition, it was where the seabed was made of sand with no expectation of much holding power and where there was a strong tidal wave of up to 3 knots with a risk of the anchor being dragged, should the weather get worse. The Master and the Chief Engineer of Hebei Spirit should have definitely kept the main engine ready for immediate use in accordance with STCW, the ship's fleet operating manual and the crew's seamanship. However, they replaced an exhaust valve on the main engine which requires 3 to 4 hours of work, thus failing to keep the main engine ready for use while anchored. The no. 3 cylinder cooling water valves of the main engine were closed for the replacement of the exhaust valve, and was kept closed even after it was completed.

As a result, the main engine was unusable before imminent collision. Conclusively, because of high temperature of the no. 3 cylinder's cooling water due to incomplete maintenance of the main engine, the ship could only run at dead-slow speed. In other words, the main engine was unusable for 6 minutes and 30 seconds, from 06:58 to 07:04:30, on the 7th, before imminent risk of a collision. Thus, Hebei Spirit lost the opportunity to avoid the collision with operating main engine at high speed.

The speed of Hebei Spirit's main engine automatically slowed down at 06:58. They argued that the factor causing the engine to slow down disappeared at 07:01 and that they fully recovered the main engine to normal condition for use soon after. However, in the event that auto slow down occurred while the engine was being controlled from the bridge, it is possible to reset (NABCO Manual "Reset of automatic emergency slow down") the engine slow down to normal condition, only after removing what caused the engine to slow down and then setting the telegraph on the bridge to a lower position than dead slow.

Therefore, even if the cooling water valves of the no. 3 cylinder was opened at 07:01 to remove the cause of the auto slow down, this is deemed as not resetting the telegraph on the bridge until Hebei Spirit made dead slow astern at 07:04:30. Thus, it would have been unable to manoeuvre the ship under the unusable condition of the main engine for at least 6 minutes and 30 seconds, from 06:58 to 07:04:30.

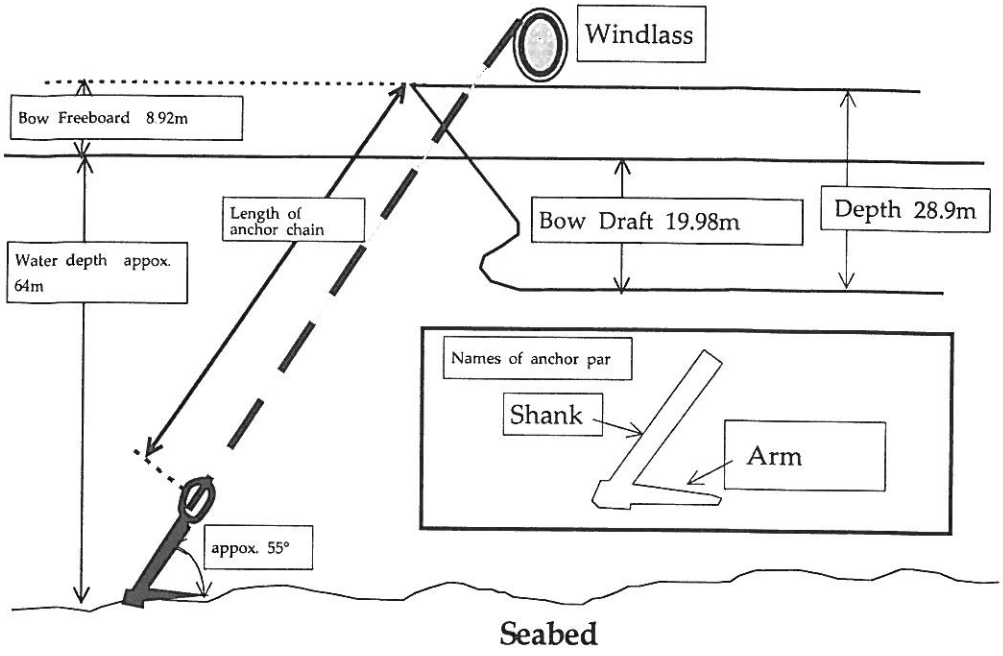
At the time of the accident, Hebei Spirit neglected maintaining readiness of the main engine, making it unusable at the time of urgency and when required for use to avoid the collision. This was deemed a direct cause of the accident.
(Direct cause 11 of the collision: Negligence in maintaining readiness of the main engine)

4.1.3.4. Counter measures taken by Hebei Spirit Master to avoid the collision

Hebei Spirit Master stepped on the bridge upon the call from the Chief Officer of Hebei Spirit at 06:06, exactly one hour prior to the time of collision at 07:06. Despite the requests made by the towing fleet and the VTS Center to heave the anchor up, the Master decided to release the anchor chain for about 100 meters by maintaining the main engine at dead slow astern since he deemed heaving up the anchor chain would cause the vessel to move even closer to the towing fleet. From the time the vessel initiated the main engine at 06:17 to the time of collision at 07:06, the engine actively operated only for a total of 20 minutes; 1 minute slow astern, 30 seconds half astern, and 18.5 minutes dead slow astern.

Whether the Master's counter measures were appropriate are examined here. First, was he able to heave up the anchor to avoid a collision? The calculations indicate that he could.

Although a total of 8 shackles of anchor chain was under water from heavy seas, an extended catenary could have been formed and could be calculated. Diagram 3-2 shows the method applied to obtain the shortest length of the anchor chain from the bow freeboard line of the ship to the bottom of the sea at zero holding power.



[Diagram 3-2] At 0 holding power and under a weak external force, the length of the chain could be appoximately 85 meters (about 3 shackles) from the seabed to the bow freeboard line of the ship, given the depth of water and the structure of Hebei Spirit. A longer catenary distance would have been formed due to heavy seas on the day.

When H is the height from the upper deck to the seabed,

H = Water depth + Freeboard bow line = 64 + 8.92 = 72.92 m

Angle of anchor shank = appox. 55°

Length of anchor shank: Ls = 3.96m

When Lc is the distance from the head of anchor to the ship, L, the total length of anchor from the deck to the base of the shank, can be;

L = Lc + Ls (m),

Then H = L x sin55° = L x 0.8195 = (Lc + Ls) x 0.8195 = (Lc + 3.96) x 0.8195.

As H was previously calculated to 72.9m,

72.92 = (Lc + 3.96) x 0.8195

Therefore, Lc = (72.92 / 0.8195) - 3.96 = approx. 85 m.

According to this calculation, the total length of anchor chain will be approximately

85 meters (about 3 shackles) at 0 holding power under weak external force.

Given that the wind force at the time of 15-18m/sec (Beaufort Scale 6-7) from the NWN and wave height of about 4 meters, it is obvious that a substantial power of external forces on the hull of Hebei Spirit would have at least 2 more shackles of catenary. (The catenary length of the large crane barge Samsung No. 1 calculated under the same weather condition is approximately 214 meters and approximately 7.8 shackles. However, as each anchor chain has different physical characters, its holding power may vary as well.)

If so, at least 5 shackles of anchor chain would have been drawn out of seabed. Taking non-tension catenary of 5 shackles off from the initially released 9 shackles, less than 4 shackles of anchor could have been hove up with tension in about 12 minutes (4 shackles x 3 minutes). Taking the adverse weather conditions into account, Hebei Spirit could have hove up 4 shackles of anchor in less than 20 minutes to reach the 0 holding power from which she could manoeuvre the main engine full astern to avoid the approaching fleet.

Since the Master had about 30 minutes to manoeuvre the ship from the time he observed the towing fleet, which was approaching at about 1-1.5 knots from 0.7 miles away till collision, it is believed that he had just enough time to avoid the accident if he hove up the anchor, advanced the ship for about 100 meters, then engaged the main engine full astern. This measure should be sought because the seabed is not composed of clay but sand, which has a weak holding power. It is especially believed that the ship could avoid the fleet by turning itself to the starboard side because it was approaching her port bow. And heaving up the starboard anchor with a hard starboard rudder could have made the ship quickly turn starboard. Besides the theoretical analysis, a number of evidence indicates that Hebei Spirit was moving that way at the time of the accident.

Next, another analysis was carried out to find the possibilities of Hebei Spirit

avoiding the collision by directly dragging the anchor with her main engine. The skill to drag anchor has been preferred by most seamen as it is extremely effective to evade traffic in narrow ports.

In conclusion, Hebei Spirit could have dragged the anchor with its 134 tons of power [table 6] from the main engine with full astern because the holding power of 9 shackles of anchor drawn from it is calculated to be 108 tons, based on the weight of anchor and anchor chains, the physical composition of seabed, the depth of water, and other external forces, including the tidal current of 1.5 knots. Even if 13 shackles of holding power of approximately 134 tons had been drawn, the Master could have been able to maneuver it astern fast enough to avoid the collision as external forces such as tide and wind, could have been allowing her to drag the anchor. In fact, Hebei Spirit dragged the anchor over 100 meters southward from the point of anchoring to the point of collision, even if it only manoeuvred dead slow astern and released the anchor alternately. It was confirmed that the Master of Hebei Spirit acknowledged the anchor was dragging when the Master of Samho T3 informed him of his observation through VHF.

Whether the Master of Hebei Spirit's argument that releasing the anchor for 100 meters was his best countermeasure to avoid the collision, is evaluated here. Simply speaking, the distance that the ship could move by releasing the anchor chain could barely be 100 meters, so it could not be an effective way of avoiding collision. This method is acceptable only when there's no other way of avoiding collision for ships anchored in a safe designated area, in narrow channels or ports, where there is not enough distance to evade the traffic and ships that often approach at a very short notice and a very close distance.

Taking it into account, it is alleged that the Master of Hebei Spirit had failed to make a sound and timely judgement under given circumstances that the ship was anchoring in a wide open area where there was enough space for it to manoeuvre. And he had about 30 minutes to avoid collision as described previously. Under such

conditions, dragging away from the approaching fleet with the main engine engaged in full astern is believed to be one of the most effective means of avoiding collision.

This analysis can be supported by the fact that it might not be difficult for properly trained seafarers to judge that 100 meters of slackened anchor chain could never be a safe distance from the towing fleet, especially when it was approaching at a noticeably changing angle and CPA pulling with about 700 meters towing wire swaying from side to side. To avoid imminent risk of a collision, rather than the alleged measures he took, the Master should have sought immediate actions by either dragging the anchor with the main engine at maximum power or making a sharp starboard turn by heaving up the starboard anchor with a hard starboard rudder, with the main engine at maximum power.

That is why a series of misjudgement or a lack of responsibility of the Master should be held accountable for the accident as he should be obliged to tender professional judgement especially under special circumstances herein. The Master of Hebei Spirit should have sought all counter measures to avoid such accidents. He is at fault for not having fully operated the main engine even by dragging the anchor and for having only slackened some anchor chain shackles.

Given the special situation in which the towing fleet was "not under command," Hebei Spirit is substantially responsible for having failed to actively seek effective counter measures such as dragging the anchor with her main engine to avoid the approaching fleet and for having caused the collision.
(Cause 12 of collision: Hebei Spirit is substantially responsible for its inappropriate action to avoid the collision)

4.1.4. Boram Co., Ltd.

Boram Co., Ltd. signed a service contract with Samsung Heavy Industries Co., Ltd. for consignment management of tugboats Samsung T-5 and Samsung No. 1, and

anchor boat Samsung A-1. Under the contract, the company was to follow the regulations of Samsung Heavy Industries Co., Ltd., for the safety management according to instructions given by Samsung Heavy Industries Co., Ltd. in operating the towing fleet and crane barge Samsung No. 1 to manage the crew on board the ships when needed. Boram Co., Ltd. undertook simple maintenance, repair or human resource management, while Samsung Heavy Industries Co., Ltd. had comprehensive control over the operation of the towing fleet.

However, the Master of Samsung T-5, who was under direct command and supervision of Boram Co., Ltd., signed the towing certificate for towing operation jointly with the surveyor. Yet he did not observe proper towing procedures described by the approved towing check list only to carelessly undertake the towing test and its implementation.

In addition, due to a lack of commanding system of the fleet and the safety management system, the fleet failed to implement the navigational recommendation to shelter from adverse weather condition. As the towing wires broke, it failed to drop emergency anchor and led to collision, lacking understanding on the risk of coastal navigation in the winter in the Yellow Sea, where adverse weather conditions occur frequently. Thus it is considered to having provided a direct cause to the collision.

Negligence of Boram Co., Ltd. is partially responsible for the direct cause of the accident, as it failed to maintain proper preparations and support, and to provide safety management and commanding systems.
(Cause 13 of collision: Improper safety management by Boram Co., Ltd.)

4.1.5. Samsung Heavy Industries Co., Ltd. Co.

Samsung Heavy Industries Co., Ltd., charterer and operator of the towing fleet - namely tugboats Samsung T-5, crane barge Samsung No. 1, and anchor boat Samsung A-1 - entered into a service contract with Boram Co., Ltd. for the ships' consigned

management. Under the service contract, Boram Co., Ltd. had to follow the safety management regulations of Samsung Heavy Industries Co., Ltd. And the towing survey for the insurance of barge Samsung No. 1 was applied at the expense of Samsung Heavy Industries, which was in a position to lead the towing fleet's practical safety management.

The operation plan of this towing fleet was to be made according to the work schedule of Samsung No. 1. Samsung Heavy Industries Co., Ltd. set forth the work schedule of Samsung No. 1 and instructed its towing navigation to Boram Co., Ltd. Therefore, Boram Co., Ltd. was only to undertake simple services, such as the maintenance, repair or provision of personnel for the fleet.

Samsung Heavy Industries Co., Ltd. is therefore recognized as commanding and supervising the operation of the towing fleet comprehensively. However, Samsung Heavy Industries Co., Ltd., which has ample specialized human resources and information related to ship operation, had left Boram Co., Ltd to delegate to the tugboats' Master the implementation of the operation's important parts for the success of practical navigation safety, such as the composition of the towing wire as specified in the survey report or the decision to take shelter in emergency. All of the above were critical to allow the towing fleet to tow the large crane barge in the West coast of the Republic of Korea in the winter, during which severe weather conditions are expected.

This is deemed as having been caused by lack of a safety management system at sea and lack of realization of sea perils.

Lack of awareness of Samsung Heavy Industries Co., Ltd. of the towing fleet's navigational safety and absence of a safety management system at sea would be an indirect cause of the accident.
(Cause 14 of collision: Absence of a marine safety management system of Samsung Heavy Industries Co., Ltd.)

4.2. Causes of the mass marine pollution

As the collision accident initially caused the marine pollution, it is important to establish a causal relationship between the collision and marine pollution. Whether the collision solely caused the pollution or is an isolated factor; or whether any other factors expanded the scale of the marine pollution; are examined here. In particular, it is even more evident in the case that the damage of the marine pollution accident is substantially more serious than the collision. As shown earlier, it was clear that the towing fleet provided the main cause of pollution since the marine pollution was caused by the collision. However, since not all collision accidents of hazardous substance carriers lead to a mass pollution accident and the scale of the consequential pollution would heavily depend on how much effort was made to control oil leakage, it is essential to make a clear review in order to prevent the recurrence of similar accidents and see if pollution expanded from lack of efforts made to control the oil leakage.

If the above considerations are omitted from this kind of accident and a causal relationship between the collision, the primary cause of the pollution, and the mass pollution is recognized, we cannot expect and seek effective measures to control the occurrence of similar mass pollution accidents, when there is a collision between hazardous substance carriers. That is why it is necessary to examine efforts made to deter oil leakage in all collision accidents of oil tankers.

Related to this, Article 48-2 of the 「Marine Pollution Prevention Act」 and Article 89 of the 「Enforcement Regulations of the Act」 regulate that ship owners, Masters, or marine facility owners seek immediate measures, such as transporting the pollutant to another ship or marine facilities, emergency repairing of damaged parts, and following preventive action to minimize the release or spreading of oil in the event of any possibility of leaking pollutants from ships or marine facilities arising from any accident of stranding, collision, sinking, and fire on ship or marine facilities.

It will be most appropriate to determine whether Hebei Spirit duly undertook the procedures described in Shipboard Oil Pollution Emergency Plan (hereinafter referred to as the "SOPEP") which was approved by the administration in accordance with resolution MEPC.54 (32) 「Instruction for Development of Marine Oil Pollution Emergency Plan」 revised by MEPC.84 (44) adopted from MEPC of IMO, pursuant to 「Chapter 5, Regulation 37 of Addendum to Marine Pollution Prevention Convention, 73/78 (MARPOL), along with Article 10 (SOPEP) of the action instruction standard of the 「Marine Pollution Prevention Act」 (changed into the Marine Environment Management Act).

Although the cargo oil leakage was initiated by the collision between the towing fleet and Hebei spirit, appropriate actions could have minimized the scale of the marine pollution. The causal relationship between the collision and the marine pollution is examined by looking into the counter measures taken based on SOPEP by Hebei Spirit after the collision.

4.2.1. Shipboard Oil Pollution Emergency Plan (SOPEP)

SOPEP sets forth emergency measures to be taken, by classifying the responsive actions to be taken to prevent oil leakage under two different situations; oil leakage during transportation in loading or unloading, and oil leakage caused by the casualty to the vessels' hull plating. SOPEP prioritizes the duties of the master that he should ensure the safety of human life and at the same time, prevent pollution by all means in case of a marine accident. With respect to this accident, the major categories of responsive actions described by SOPEP in "leakage of oil and/or harmful liquid substance" are as follows;

- Secure oil spill area
- Transfer oil to a safe reservoir from the damaged tank
- Reduce internal pressure in oil spill tank
- Control the vessel's trim and/or healing to prevent further oil leakage by applying ballast water as necessary.

These measures shall not be neglected in protecting marine environment by undertaking safety actions for human lives and ships' safety as well. The actions that Hebei Spirit took under each category are examined here.

4.2.2. Damage control

4.2.2.1. Securing oil spill area

As soon as oil starts to leak from an oil tanker due to an accident to a ship, the damaged tank should be secured immediately. Then negative pressure should be applied to the tank in order to set back the leak. Upon quickly assessing the damage and as the situation permits, wooden wedges or collision mats should be used to block the leaks. In case of Hebei Spirit, holes on nos.1, 3 and 5 port side tanks were located between 5 to 7 meters above water line and nos.1 and 3 holes were relatively small with length and height of 300 mm x 30 mm and 1,200 mm x 100 mm, respectively.

Although the no.1 tank was inaccessible, every effort should have been made to secure the holes temporarily, by turning the vessel in a way that the holes would face the wind. Instead, the Master and crew members of Hebei Spirit did not make any attempt for the first 2.5 hours before an officer of the Korean Coast Guard arrived on the scene and only afterwards commenced transferring oil from the damaged tanks.

4.2.2.2. Transferring oil from tanks spilling oil

Hebei spirit had spent 3 hours to measure ullage of the cargo tanks, ballast tanks, and other empty tanks at the Master's order and began transferring the oil 3 hours after the leak.

First, the amount of oil that could have been saved from the spill if it were moved to other tanks up to full capacity, is calculated here.

The total capacity of the ship's cargo tanks is 1,984,331 barrels [315,483.5㎥], and the volume of loaded oil is estimated to be 1,928,246 barrels [306,567.0㎥] ([Table

2-1]) at 89.1 Fahrenheit which leaves an empty volume of 56,085 barrels [8,916.4㎥] in the ship. If the spare space of the damaged tanks (10,438 barrels[1,659.4㎥]) is subtracted from the total empty volume, 45,647 barrels are left [7,257㎥] ([Table 2-2]). Having arrived at Daesan Port, the mean temperature of the oil in Hebei Spirit's cargo tanks dropped to 65.9 Fahrenheit, which expanded the damaged tanks' empty volume to 60,922 barrels [9,685.46㎥] or 9,661.78 kilo liters ([Table 2-2]), excluding their spare space.

That means a total of 9,661.78 kilo liters could have been reserved from the 12,547 kilo liters leaked into the sea, if oil had been transferred into the spare space of other tanks, leaving only 2,885.22 kilo liters leaking from the accident (Table 9). Given the low temperature, the spare space of non-damaged tanks could have been checked by the ullage in the cargo control room (CCR) and it would be over 2 percent. If Hebei spirit had transferred oil from damaged tanks in the order of nos. 5, 1, and 3, using three cargo oil pumps with a capacity of 4,500 tons per hour each, and two air pumps, oil leakage could have been stopped in a short time and approximately 60,922 barrels (9,661.78 kilo liter) of the total spilled oil, could have been prevented from spilling.

Although this is a theoretical calculation of the spare space and the actual volume may need further calculation using Liquid Cargo Handling Simulation, to consider other factors such as heeling created by transfer of oil into account, up to 99.5 percent of oil could have been reserved from the spill under any circumstances, if timely and proper measures had been taken. In summary, it was clear that a vast amount of oil spilled into the sea by Hebei Spirit, because it neglected responsive action.

4.2.2.3. Reducing the internal pressure of the oil leaking tanks

When cargo oil was leaking from the holed port side tanks nos. 1, 3 and 5, Hebei Spirit should have lowered the pressure of the damaged cargo oil tanks to maintain the negative pressure, in order to prevent further oil leakage. However, they supplied

inert gas at around 10:00 on December 7, creating positive pressure and accelerating the leakage. In this case, it should have closed all valves that connected the cargo oil tanks, such as the inert gas piping system valve on each tank and then seal off the high velocity pressure and vacuum valve line, in order to maintain negative pressure in the tank by cutting off the external air coming in. The Master and the Chief Officer both argue that, when negative pressure is formed in the tanks from cargo oil leakage, fresh air enters the tanks, raising the possibility of an explosion, that they supplied inert gas into the tanks.
This issue is examined herewith.

The risk of an explosion after a collision is considered a risk when cargo oil leaks outside the cargo tank. There are three possibilities: (1) the case of inflammable gas from the leaked cargo oil flowing into the air surrounding the ship, heightening the risk of an explosion, (2) air flowing in as the tank leaks oil, creating a risk of an explosion inside the cargo oil tank, and, (3) cargo oil flowing into other enclosed spaces in the ship (for example, into the ballast water tank and others), creating a higher risk of an explosion in an enclosed space.

In this case, the ship would produce inert gas by operating the inert gas system to turn the tank's inside into an inerting condition. If the situation created a risk of an explosion at the time of the collision, it would be inevitable to undertake all possible measures, including inerting cargo oil tank to prevent the risk of an explosion. However, if inert gas is supplied into the tanks as in this case, when cargo oil has leaked from the holed tanks and is causing marine pollution, the pressure inside the tanks heightens, drastically increasing the amount of oil leaking from the cargo oil tanks. Accordingly, the degree of an explosion or risk of an explosion needs to be closely reviewed to determine whether to blow gas in and when to supply gas into the tanks.

In fact, after the collision of Hebei Spirit, the Master instructed the Chief Officer to measure the ullage of all cargo oil tanks and to check sea water flowing in and out

of oil area, the ballast water tank, void space, the engine room and all other tanks. And it took approximately 3 hours. At around 10:30, they supplied inert gas into all the cargo oil tanks. Even though both the Master and the Chief Officer concertedly argued that, "the inert gas was supplied with a pressure of +100 mmAq and that the increase of leakage from supplying inert gas was minimal", their argument was difficult to accept.

Regarding the pressure of the inert gas supplied into the cargo tanks, first, the inert gas passed the deck seal that is in place to prevent gas blown through the blower from the back draft. Thereafter, it was supplied into the cargo tanks. Finally, the pressure of the inert gas being supplied into the cargo tanks was adjusted by the high velocity and vacuum valve (operated under +2,100mmAq or -700mmAq) on the each tank top, respectively. Therefore, maintaining inert gas pressure by adjusting the speed of the blower and the gas flow to +100mmAq, is not easy. In addition, the fact that there was no evidence of inert gas supplied into the no. 4 ballast tank (p), in which oil had leaked from the damaged adjacent cargo oil tank, is indicative that it was not an act of supplying inert gas under the closely deliberated plan of the Master or the Chief Officer. Instead it was an abrupt act of operating the inert gas system concerning the air penetrating the port side cargo oil tanks nos. 1, 3, and 5. Therefore, it is difficult to accept the argument that inert gas did not accelerate the oil leaking speed.

If more careful actions had been taken by the Master or the Chief Officer, they would have recognized that if inerting was needed, first, the inert gas system should have isolated the damaged cargo oil tanks from those without damage. Supplying inert gas into the undamaged cargo oil tanks while cutting off the inflow of inert gas into the damaged tanks in order to lower the internal pressure of the damaged oil tanks, would have been more reasonable. Rather, in order to prevent an explosion, inerting only the no.4 ballast water tank instead of the damaged cargo oil tanks should have been considered more seriously. Ultimately, supplying inert gas into this tank is required.

During the second ruling at the Korean Maritime Safety Tribunal, the marine judge questioned, "when were you first aware of the leakage of the cargo oil into the no. 4 ballast water tank (p)? And how did you blow inert gas into the said tank?". The Master responded, "I do not recall exactly when we realized oil was leaking into the no. 4 ballast tank (p), but upon realization, we measured the oxygen content in the tank, which was 4 percent at the time. Therefore, we did not supply any inert gas. Perhaps the amount of oxygen in the tank lowered because inert gas was supplied into cargo oil tanks nos. 3 and 5 (p), and inert gas began to flow into the no. 4 ballast tank."

From the above, when loading cargo oil at the loading port, the full volume of the ballast water must have been discharged and the ballast tank must have been empty with fresh air at the loading port, and as such, a small volume of cargo oil (approximately 326 kilo-liters) is deemed to have flown into the no. 4 ballast tank because of the damages or cracks. In light of the situation, the damage or crack in the no. 4 ballast tank was deemed not significant. If inert gas were supplied at a low pressure of only 100 mmAq as stated by the Master, it would have been impossible for the entire volume of fresh air in the ballast tank to be replaced with inert gas of only 4 percent of oxygen contents. Based on the above, they must have carelessly supplied inert gas into all cargo oil tanks, as under customary procedures.

Therefore, the Master and Chief officer of the Hebei Spirit must have supplied inert gas into the oil leaking tanks without conducting a close review of the tanks when they added inert gas.

Next, whether or not there was a risk of an explosion following the damage of the cargo oil tank at the time of the accident is examined. For a risk of an explosion to exist, certain conditions would need to have also existed. These conditions would

include oxygen levels of 11.5 percent or more, an inflammable gas with the appropriate necessary density and an ignition source (flame and/or heat). But the cargo oil loaded into the ship was "black oil" with a high viscosity and a low probability of carrying static electricity, the damaged area was not that large, and cargo oil blocked air from incoming into the damaged tanks. Unless air had flown into the upper part of the tank, the inflammable gas volume on the upper part of the tank would have been maintained at a non-inflammable state (Too Rich or over rich), and even if the damaged part did have the air penetrate into the tank, the possibility of an explosion would have been very low. In the worst case, if the oxygen volume in the tank and the inflammable gas volume did create the conditions for an explosion, the ignition source (flame, heat) expected at the time of the accident would not be present. Thus, the possibility of an explosion would be very limited.

From the time of the accident to the time of supplying inert gas into the cargo oil tanks for approximately three hours until around 10:00, there was no actual explosion. Even though some of oil from the no. 3 cargo oil tank (p) had poured through the damaged bulkhead into the no. 4 ballast tank (p), there was no actual explosion. Accordingly, their argument is difficult to agree with.

In this regard, as a result of the review completed by the Marine Research Institute of Seoul National University, the following conclusions were made: (1) In the event the inside of the tank was damaged, there was no possibility of an explosion even with an ignition source (flame or heat) being created from the low oxygen contents that may have been inside the tank; (2) If an explosion would have occurred outside the ship, the area for a possible explosion would have been the vertically lower part than the damaged part, but even this is extremely limited due to the lack of ignition and (3) in the event inert gas were supplied without sealing off the damaged tank, the speed of oil leaking from the tank would have accelerated, and the leakage

amount at the time without supplying inert gas would have been only 10 percent of when inert gas were supplied.

Therefore, supplying inert gas into the tanks of Hebei Spirit, where cargo oil was leaking without isolating or sealing off all pipes connected to the damaged cargo tanks at the time of the accident, is deemed an inappropriate action by SOPEP. In addition, it is considered an inappropriate emergency response that accelerated the speed of oil leakage. As a result, it is considered an action resulting from lack of relevant knowledge and experience by the Master and the Chief Officer.

4.2.2.4. The optimal condition to prevent additional leakage of oil, by adjusting the ballast water etc.

In order to reduce the amount of leakage from the cargo oil tank on the portside, the ballast water tank was supposed to be promptly filled in on the opposite side of the ship, the starboard side. However, only a small volume of water was ballasted, considering the risk to the crew on deck. Given this reason, approximately only 5-6° of healing to starboard side was maintained, which was not enough to reduce the volume of oil being released.

4.2.3. Sub-conclusion (cause of mass marine pollution)

Whenever a marine accident occurs, the top priority to be considered is human life, then the ship and cargo. If the accident is accompanied with leakage of a harmful substance, like oil, due to a collision, stranding and other reasons, the action to reduce the amount of leakage as much as possible to protect the environment should be taken into account as well as measures undertaken to ensure the safety of all human life and the ship. MARPOL also sets out the actions to be taken.

Taking appropriate actions at the early stage of an accident would be more important than anything else, to prevent the escalation of environmental damage, which would comply with the requirement of the Marine Pollution Prevention Act or MARPOL. However, as shown earlier, Hebei Spirit at the time of the accident, did not take any active actions to block the oil leakage area, by transferring oil from the damaged tanks to undamaged tanks. It nor attempted to build up an optimal condition to prevent additional oil leakage by adjusting ballast condition or internal pressure in the damaged tanks. Instead, Hebei Spirit, blew in inert gas into the damaged tanks, which resulted in accelerating the spill.

This accident is clearly different from other cases that allow discharging oil into the sea for the purpose of saving lives and securing the safety of a ship at sea.
The passive and default actions taken by Hebei Spirit, as described above, contributed to the cause of the accident substantially. Most of all, there was a lack of basic perception that environmental protection should be upheld as well as saving lives, securing the safety of the ship and cargo at sea.

Given that the Master of Hebei Spirit operated the engine at ahead direction and the hard port rudder to protect its engine room after the collision, it is regrettable that he did not try to manoeuvre the ship to avoid the collision of the cargo oil tank as he had done after the collision.

5. Conclusion

The said accident happened, because the towing fleet composed of tugboats Samsung T-5 and Samho T-3, anchor boat Samsung A-1 and crane barge Samsung No. 1, did not respond at the early stage when the weather got worse, while towing voyage. The towing fleet continued to sail without taking safety measures. It neither warned other nearby ships nor anchored in emergency, until it lost towing ability due to bad

weather and got pushed over by heavy seas. Samsung T-5's towing wire snapped when the towing fleet neared oil tanker Hebei Spirit and Samsung No.1 drifted toward Hebei Spirit.

However, the following are also causes: the fact that Hebei Spirit did not promptly take active action to avoid the collision because of anchor watch negligence and idle response, despite being anchored where it could obstruct coastal traffic; and the fact that it did not take active action to avoid the collision, because its main engine was out of control before imminent danger of a collision, due to negligence in preparing it beforehand.

Marine pollution happened because cargo oil leaked into the sea from holes in Hebei Spirit's cargo oil tanks, caused by the collision. But marine pollution resulted in mass pollution, because of Hebei Spirit's inappropriate and passive emergency response after the collision.

6. Lessons learned

6.1. Importance of the towing survey

The towing survey is undertaken for the purpose of insuring all towed objects and is a contractual procedure between the towing companies and the insurer. The object to be surveyed is closely related to whether the towing fleet can undertake safe voyage or not. With this, the conformity of the survey is a very important part in terms of its impact on the safety of human life and the towing fleet itself.

Therefore, the survey is not just a formality required to obtain insurance, but the towing fleet should not fail to perform the required conditions or compliances set forth in the survey. The survey method and contents have to be scientific and

reasonable, while also in accordance with the pertinent regulations. The towing fleet must also fully comply with the conditions set forth in the survey.

6.2. Weather information

Regarding this accident, the Master of the towing fleet got weather information that forecast heavy seas in the far seas at 20 miles off the coast in the Yellow Sea on the day following departure from port. But since their destination was 20 miles away and the towing fleet intended to navigate for approximately 5 miles off the coast, he thought the advisory would not apply or cause much impact. However, even if their destination was 20 miles away, there is no such boundary set for travelling farther or nearer the coast of sea, as both weather and sea conditions have considerable impact on the near sea. Also if these conditions are sustained for long, it can have adverse effect on the near sea that masters must remember this important factor when making voyage plans.

6.3. Early warning and emergency anchoring

In this accident, the tugboats almost lost their towing ability, making maneuverability difficult under bad weather conditions, which pushed them over from their intended course and resulted in their drifting under heavy winds. The tugboats did not inform their surrounding ships or port authorities in the coastal area thus failing to give any time for them to take any early actions to avoid a collision. In addition, if maneuvering becomes difficult with only the tugboats' towing capabilities, the masters must remember that it might be better to anchor the towed barge in emergency.

6.4. Anchor watch and readiness of the main engine

Anchor watch negligence and the ship's negligence in using the main engine were deemed direct causes of the accident. Any ship that is anchored in the open sea without shelter, particularly a very large oil tanker loaded with hazardous substances

such as Hebei Spirit, is exposed to a risk of collision with other ships or of having its anchor drag. Therefore, the ship should adopt navigational watch and the main engine should be maintained for normal use, so that it can be used immediately during emergencies.

6.5. Actions to avoid the collision, while anchored

In the event an anchored ship has another ship with seriously restricted manoeuvring capabilities approaching, the anchored ship must take precautionary actions to avoid a collision, in accordance with Article 2 (a) and (b) of COLREG. In this case, Hebei Spirit was anchored in an open roadstead and it tried, but failed to secure enough distance from the approaching towing fleet, because it only had its main engine operating dead slow astern and had slackened about 100 meters of its anchor chain. It is difficult to expect that slackening only 100 meters of the anchor chain would have been effective in avoiding the collision with the approaching towing fleet under bad weather. It would have been more reasonable and effective to move the ship to a safer place early on, by operating the main engine at full or half speed or by heaving up the anchor chain.

6.6. Compliance with SOPEP

Recently, there has been a significant rise in the number of collisions involving towing fleets off the coasts of the Republic of Korea. This accident was one of the many collisions, but it turned into a disastrous mass oil pollution accident, because Hebei Spirit neglected SOPEP. The crew and oil tank operators should make efforts not only to secure the safety of human lives, the ship and its cargo, but also prevent marine pollution when an accident results in pollution, such as oil, leaking from a ship.

6.7. Towing survey by marine insurance company

A towing survey is carried out to confirm the safety and fitness of the towed ship for insurance. The survey must comply with the conditions set out by the insurance company, which is specified in the survey report, to ensure that the applicable towing fleet is safe and able to carry out its task safely. Therefore, the towing fleet must abide by the conditions and navigational recommendations set forth in the insurer's towing survey report. The insurer must also check the towing fleet's overall performance and whether their preparations for departure are ready for safe operation. If the towing survey is carried out carelessly or neglected, it is difficult to expect the towing fleet's successful voyage. Accordingly, the insurance company should remember this when granting insurance.

6.8. VDR records

The VDR contains very important evidentiary data that can be used to clarify the causes of a marine accident, such as, collision, sinking and others that have to be preserved as well. At the time of this accident, Hebei Spirit was equipped with a VDR, in accordance with SOLAS regulations, but it did not save the data. In addition, the surveyor of the insurance company carried it off the ship without permission from relevant authorities. The VDR can save data only up to 12 hours. As a result, the VDR data could not be used in clarifying the cause of the accident. Therefore, the VDR's retention time should be extended reasonably. In addition, at the time of the accident, the VDR should have been accessed by the investigator of the marine accident, with proper authority to do so. It should also be mandatory for the ship owner and/or masters to make the VDR available to relevant authorities.

6.9. Cargo officer on VLCC

Given that the officer in charge of cargo in this accident, neglected anchor watch and was unable to undertake the pollution emergency plan, there is high possibility for an

officer in charge of cargo on VLCC to neglect navigational and anchor watch due to fatigue or preparations to load and unload, consequently creating the possibility of a marine accident. Therefore, excluding the officer in charge of cargo on a VLCC from navigational and anchor watch should be considered. In addition, when the officer has little experience in VLCC cargo operation, it would be desirable for the officer to have the previous officer in charge of cargo, working together for a certain period of time, in order to transport the cargo oil safely and to appropriately respond to emergencies.

6.10. The need to improve the oil tanker design

Oil pollution from an oil tanker can have serious consequences. However, in the event of a SBT+PL type oil tanker being involved in a collision or stranded fully loaded with oil, and when the cargo oil compartment is completely separate from the ballast water system, it can obstruct attempts to reduce the amount of oil leakage from the ship by transferring oil from damaged tanks to any other tanks, such as the ballast tank, etc. On the other hand, IMO has enacted and implemented international conventions requiring all oil tankers to operate with a double hull structure starting in 2015. Nonetheless, such problems can also occur in case of a double hull oil tanker. The accident should serve as an opportunity for authorities in charge of the safety management of oil tankers to closely review and improve the current international standard on separating cargo oil tanks completely from ballast tanks, by consulting with IMO.

6.11. Applying safety management system to towing fleets

Recently, the number of marine accidents has been increasing on the coast of the Republic of Korea, which is attributed to the absence of a systematic management safety program on towing fleets. The absence of a safe management system in place is one of the main causes for this accident, which arose while towing a large crane

barge. In order to prevent the recurrence of similar accidents, there is a need for a compulsory application of the 「Safety Management System of Ships」 under the Marine Traffic Safety Act on all towing fleets that tow certain objects of a certain size.

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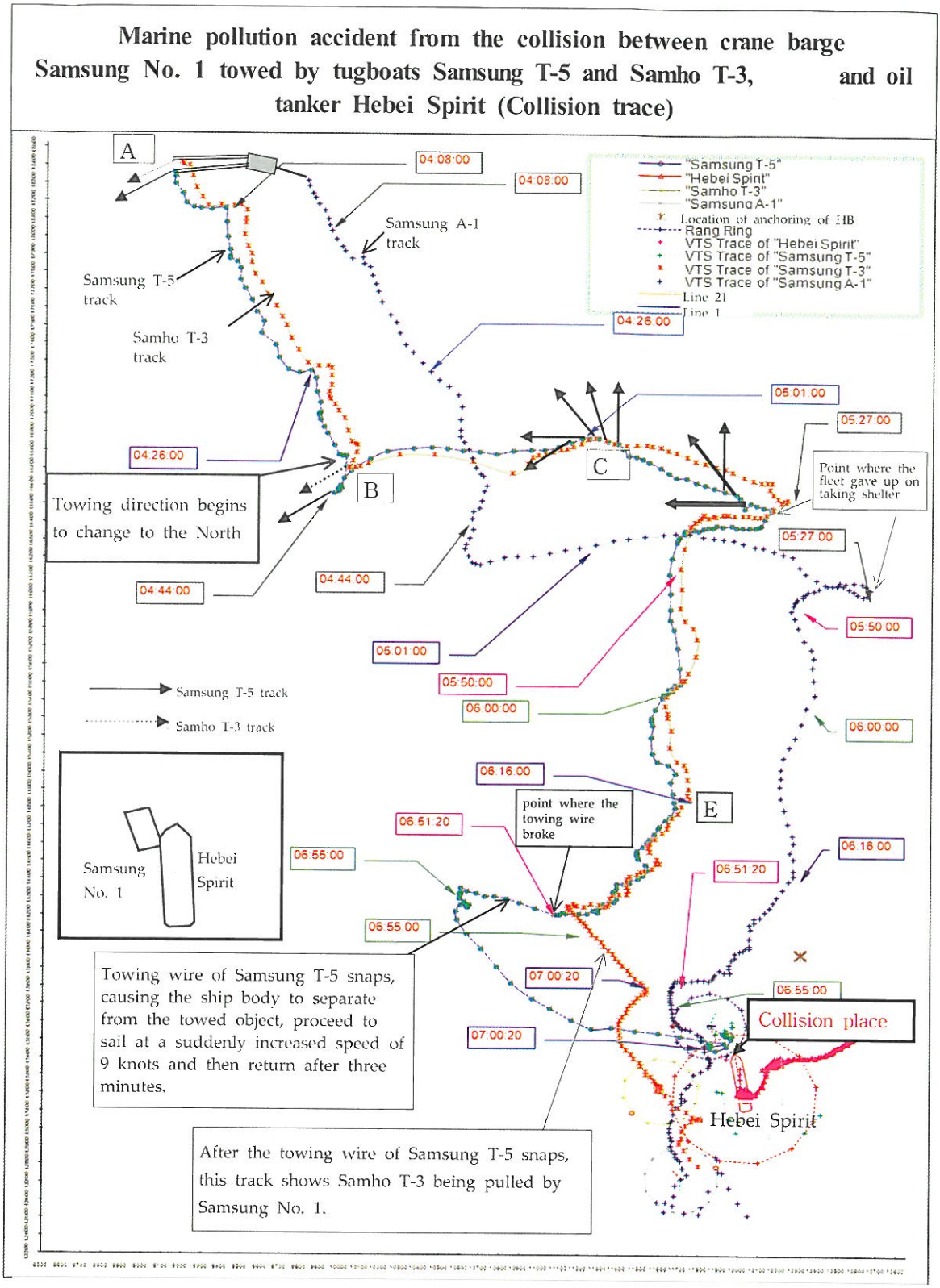
【Annex 1】 Collision trace



【Annex 2】 The Simulation trace combined with crane barge Samsung no. 1